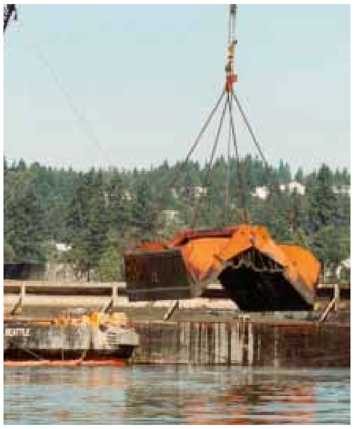
Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company



Executive Summary

Draft Final Feasibility Study

Lower Duwamish Waterway

Seattle, Washington

PREPARED BY:

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OCTOBER 15, 2010

FOR SUBMITTAL TO:

THE U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 10
SEATTLE, WA

THE WASHINGTON STATE DEPARTMENT OF ECOLOGY
NORTHWEST REGIONAL OFFICE
BELLEVUE, WA

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Acronyms Used in the Executive Summary

AOPC	area of potential concern
API	Asian and Pacific Islander
ARAR	applicable or relevant and appropriate requirement
BCM	bed composition model
CAD	contained aquatic disposal
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	chemical of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
dw	dry weight
EAA	early action area
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
HQ	hazard quotient
LDW	Lower Duwamish Waterway
µg/kg	micrograms per kilogram
mg/kg	milligrams per kilogram
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
n/a	not applicable
ng/kg	nanograms per kilogram
oc	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PRG	preliminary remediation goal
RAL	remedial action level
RAO	remedial action objective
RME	reasonable maximum exposure
RI	Remedial Investigation
SMS	Sediment Management Standards
SQS	sediment quality standard
STM	sediment transport model
SWAC	spatially weighted average concentration
tbd	to be determined through additional studies
TEQ	toxic equivalent
UCL95	95 percent upper confidence limit on the mean

All elements of this Draft Feasibility Study, including information on how and where to provide comments, have been made available online at: www.ldwg.org.

Key Facts about the Lower Duwamish Waterway Feasibility Study

Site Description: The study area for the Lower Duwamish Waterway (LDW) Superfund Site is 441 acres, extending over the northern five miles of the Duwamish River to the southern tip of Harbor Island. The river was modified into an engineered waterway in the early 1900s for industrial development, losing much of the natural habitat (wetlands, marshlands, and mudflats) over the years. Today, although significant sediment contamination exists, the corridor is home to people, animals, and industries, and used for navigation, recreation, and tribal fishing. This Feasibility Study (FS) identifies and analyzes a wide range of alternatives for cleaning up the waterway.

Chemicals of Concern: Contaminants include polychlorinated biphenyls (PCBs), dioxins/furans, arsenic, and carcinogenic polycyclic aromatic hydrocarbons (cPAHs), phthalates, and other chemicals.

Contaminant Risks: Human health and ecological risks exist at levels that warrant action under federal and state law. Risks to people are highest from eating fish that reside in the waterway for most or all of their life (but not salmon, which move quickly through the waterway), clams, and crabs. Lower, but still significant, health risks to people come from contacting sediment while playing on the beach, clamming, and netfishing. Animals that live in the mud and in the water, and animals that feed in the river, including the river otter, are also at risk.

Source Control: Reducing the contaminants entering the waterway is a priority to avoid recontamination of the site following remediation. The Washington State Department of Ecology's (Ecology) source control strategy for the 32 square mile drainage basin is under way now and will continue in coordination with the City of Seattle, King County, and property owners. Cleanup of contaminated sites located on properties along and near the river is described briefly but not evaluated in the FS because upland cleanups are not part of the comparison of alternatives for cleaning up contaminated sediments in the LDW. Numerous activities are in progress, and further upland cleanup is anticipated that will help control sources of contaminants.

Early Action Areas: The most contaminated areas of the waterway were targeted for cleanup early in the investigation process. Cleanups have been conducted at two hot-spot areas and three more will be cleaned up in the next few years. Waterway contaminants, especially PCBs, will be reduced by about half when these 29 acres of contaminated sediments are cleaned up.

Cleanup Alternatives for the Rest of the Waterway: This FS describes options for cleaning up the rest of the LDW, using a combination of technologies (dredging, capping, natural recovery, enhanced natural recovery, and treatment), along with institutional controls and monitoring. Federal and state criteria were used to develop and evaluate cleanup alternatives. These alternatives form the basis for selecting a final cleanup plan.

Cleanup Process and Status: Public review of this document will take place from October 18 through December 23, 2010. U.S. Environmental Protection Agency (EPA) and Ecology will use public input to finalize the FS and develop a Proposed Plan for remediation of the site. The Proposed Plan is scheduled to be issued for public review and comment early in 2012. Public comment on the Proposed Plan will be used by EPA to develop its Record of Decision for the final cleanup plan. EPA will issue the Record of Decision in 2013, after seeking concurrence from Ecology.

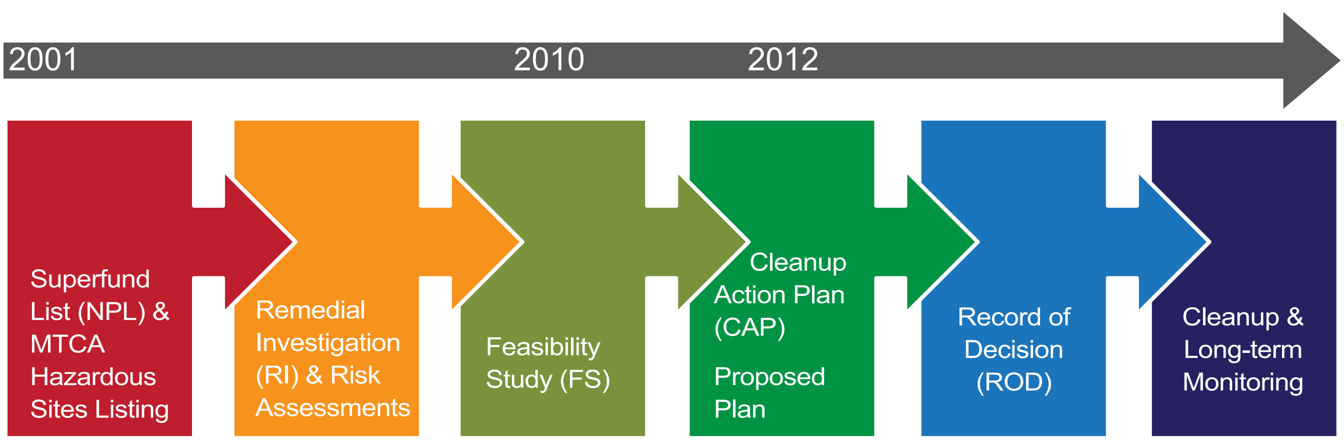
Executive Summary

This report presents the FS for the LDW Superfund Site in Seattle, Washington (Figure ES-1). It was prepared by the Lower Duwamish Waterway Group (LDWG), consisting of the City of Seattle, King County, the Port of Seattle, and The Boeing Company. LDWG signed an Administrative Order on Consent in December 2000 with EPA and Ecology to conduct a remedial investigation/feasibility study (RI/FS) for the LDW (EPA, Ecology, and LDWG 2000). The LDW was added to EPA's National Priorities List on September 13, 2001. The LDW was added to Ecology's Hazardous Sites List on February 26, 2002. Both EPA and Ecology provided guidance and input to this final draft FS.

The FS evaluates the LDW over five miles (river mile 0 to river mile 5), from just south of Harbor Island to just beyond the Upper Turning Basin at the Norfolk combined sewer overflow/storm drain (CSO/SD). It describes and evaluates a range of remedial alternatives for cleaning up the LDW. The remedial alternatives are evaluated according to the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Washington State Model Toxics Control Act (MTCA), which establish standards for evaluating remedial alternatives, selecting a remedy, and performing cleanup. This document has been prepared to obtain public input and agency review on the remedial alternatives. Input will be used to finalize the FS. EPA and Ecology will then issue a proposed plan that identifies their preferred remedial alternative for the LDW. Formal public comment will be requested on the proposed plan. After public comments on the proposed plan are received and evaluated, EPA will select the final remedial alternative, seeking Ecology's concurrence, and publish the Record of Decision.

The FS builds on a series of studies completed over the past nine years. These studies are documented in the Final Remedial Investigation (RI) (Windward 2010). The RI summarizes:

- A conceptual site model for the LDW
- Physical and biological interactions of the waterway system, including transport of sediments into, within, and out of the LDW
- The nature and extent of the contamination in the LDW
- Risks that contamination represents to people and animals that use the LDW



This Feasibility Study identifies alternatives for cleanup and compares these alternatives. EPA, Ecology, and LDWG are making this document widely available in order to obtain public input, before the agencies issue decision documents.

Scope of this FS in the Context of Other LDW Cleanup Activities

The Superfund and MTCA cleanup of the LDW includes three components: early cleanup actions, source control, and cleanup of the remainder of the LDW. The first two components are described below; this FS addresses the third component.

Early Action Areas

Five Early Action Areas (EAAs) are completed or under way. The EAAs include two early action sediment cleanups that were completed by King County in the vicinity of the Norfolk combined sewer overflow/storm drain (CSO/SD) (RM 5) in 1999 and in the vicinity of the Duwamish/Diagonal CSO/SD (RM 0.5) in 2004/2005. A much smaller sediment cleanup was conducted at the Norfolk EAA in 2003 by The Boeing Company in the vicinity of the Boeing Developmental Center's south storm drain. Three other EAAs are in the planning stages under cleanup agreements with EPA. Together, these five EAAs cover 29 acres, representing some of the highest levels of sediment contamination in the LDW. This FS evaluates options for cleanup of the rest of the LDW after the EAAs are completed. It is anticipated that cleanup of the EAAs will be completed prior to initiating any of the cleanup alternatives in the FS, and will reduce average polychlorinated biphenyl (PCB) concentrations in the LDW by approximately 50 percent.

Source Control

On-going sources of contamination to the LDW need to be controlled to the extent practicable to minimize on-going chemical inputs and prevent recontamination of the site after cleanup. Ecology is the lead agency for managing activities that identify and address sources of chemicals contributing to on-going contamination of the LDW. Ecology developed a source control strategy (Ecology 2004) to identify and manage sources of contaminants to LDW sediments that coordinates with the sediment cleanups addressed in the EAAs and in this FS. The strategy and associated Source Control Action Plans (SCAPs) for 24 individual drainage basins around the LDW provide the framework and process for identifying source control issues and implementing practical control of contaminant sources. It is important to note that in some localized areas, some recontamination may occur even with aggressive source control because of the difficulty in identifying and completely controlling all potential sources of certain contaminants that are widely released by urban activities.

The LDW source control efforts have been developed in parallel with the RI and FS and will continue before, during, and after implementation of the cleanup alternatives discussed in this FS.

Source tracing and control efforts include:

- Mapping of storm drain systems and chemical analyses of samples collected therein
- Management of discharges from storm drains and CSOs
- Inspections of local businesses that discharge or otherwise contribute to storm drains, CSOs, or directly to the LDW, and implementation of best management practices
- Upland cleanups, including remediating contaminated soils, groundwater, and storm drain solids

Ecology chairs the Source Control Work Group (SCWG), consisting of the primary public agencies responsible for source control for the LDW: Ecology, the City of Seattle, King County, Port of Seattle, City of Tukwila, and EPA. SCAPs document and prioritize source control activities for each source control area. Ecology's first priority is to address sources contributing to contamination in EAAs. Because of the dynamic nature of many source control activities, it is essential to maintain flexibility when adapting source control efforts to specific needs within source control areas. The success of source control depends on cooperation of all members of the SCWG and the active participation of businesses that must make changes to accomplish source control goals. This adaptive strategy for prioritizing source control work will continue throughout selection, design, and implementation of the long-term remedy for the LDW.

Site Description

The northernmost portion of the Duwamish River, just south of Harbor Island and the confluence with Elliott Bay, makes up the LDW. It was modified to an engineered waterway in the early 1900s to serve developing industries in Seattle. It is a saltwater wedge-type estuary influenced by river flow and tidal effects, both of which fluctuate seasonally. The 5-mile LDW FS study area (see Figure ES-1), encompasses approximately 441 acres, with an average width of 440 feet (ft). A brief description of the LDW is provided below:

Habitat: Most of the natural habitat (wetlands, marshlands, and mudflats) of the Duwamish River estuary was lost during construction of the LDW in the early 1900s and in subsequent land development. Much of the present shoreline consists of riprap, pier aprons, and sheet pile walls. Despite significant alterations in habitat, the LDW contains diverse aquatic and wildlife communities and a robust food web that includes top predators. Some intertidal habitat remains in small isolated patches, with the area around Kellogg Island being the largest contiguous area. Remaining habitat is important to various species, including threatened Puget Sound chinook salmon and other salmon species that use the LDW as a migration corridor. A number of habitat restoration and planning efforts are ongoing within the LDW.

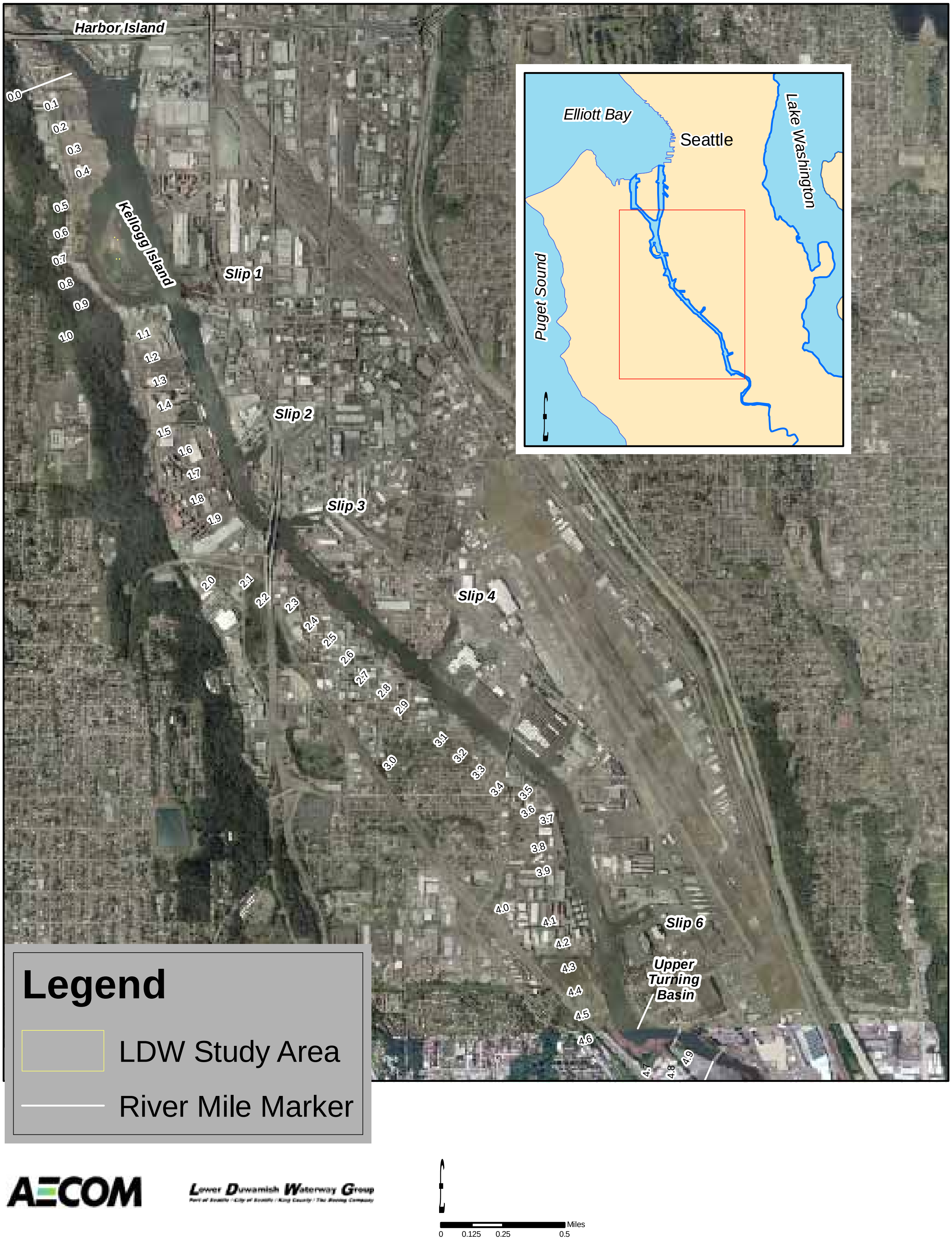
Uses: The LDW corridor is the City of Seattle's primary industrial area. Current land use, zoning requirements, and land ownership within most of this corridor are consistent with the characteristics of an active industrial waterway. Two neighborhoods, South Park and Georgetown, are located to the west and east, respectively, of the LDW. These neighborhoods support a mixture of residential, recreational, commercial, and industrial uses. The LDW supports considerable commercial navigation and is also used for various recreational activities such as boating, kayaking, fishing, and beach play. Several public parks and publicly accessible shoreline areas exist. There are plans to create additional recreational and habitat opportunities in the LDW corridor. The LDW is one of the locations of the Muckleshoot Tribe's commercial, ceremonial, and subsistence fishery for salmon. The Suquamish Tribe actively manages aquatic resources north of the Spokane Street Bridge, just north of the LDW study area. The Duwamish Tribe uses Herring's House Park and other parks along the Duwamish for cultural gatherings.

Navigation: The LDW includes a federally-maintained navigation channel and numerous privately maintained berthing areas that support vessel traffic and waterway use. Many of the berthing areas and the upper reach of the navigation channel are periodically dredged to remove deposited sediments so that navigable depths are maintained. Authorized water depths in the navigation channel vary from approximately -30 ft mean lower low water (MLLW) elevation near the mouth of the LDW to -15 ft MLLW near the Upper Turning Basin (NOAA 2009b).

Photo courtesy King County

The LDW serves primarily as an industrial and navigational corridor, with some recreational uses. It is a migration corridor for salmon and supports a fishery for the Muckleshoot Tribe. The LDW area will continue to support diverse uses into the future, as the heart of a still-growing urban area.

Figure ES-1: Lower Duwamish Waterway Study Area



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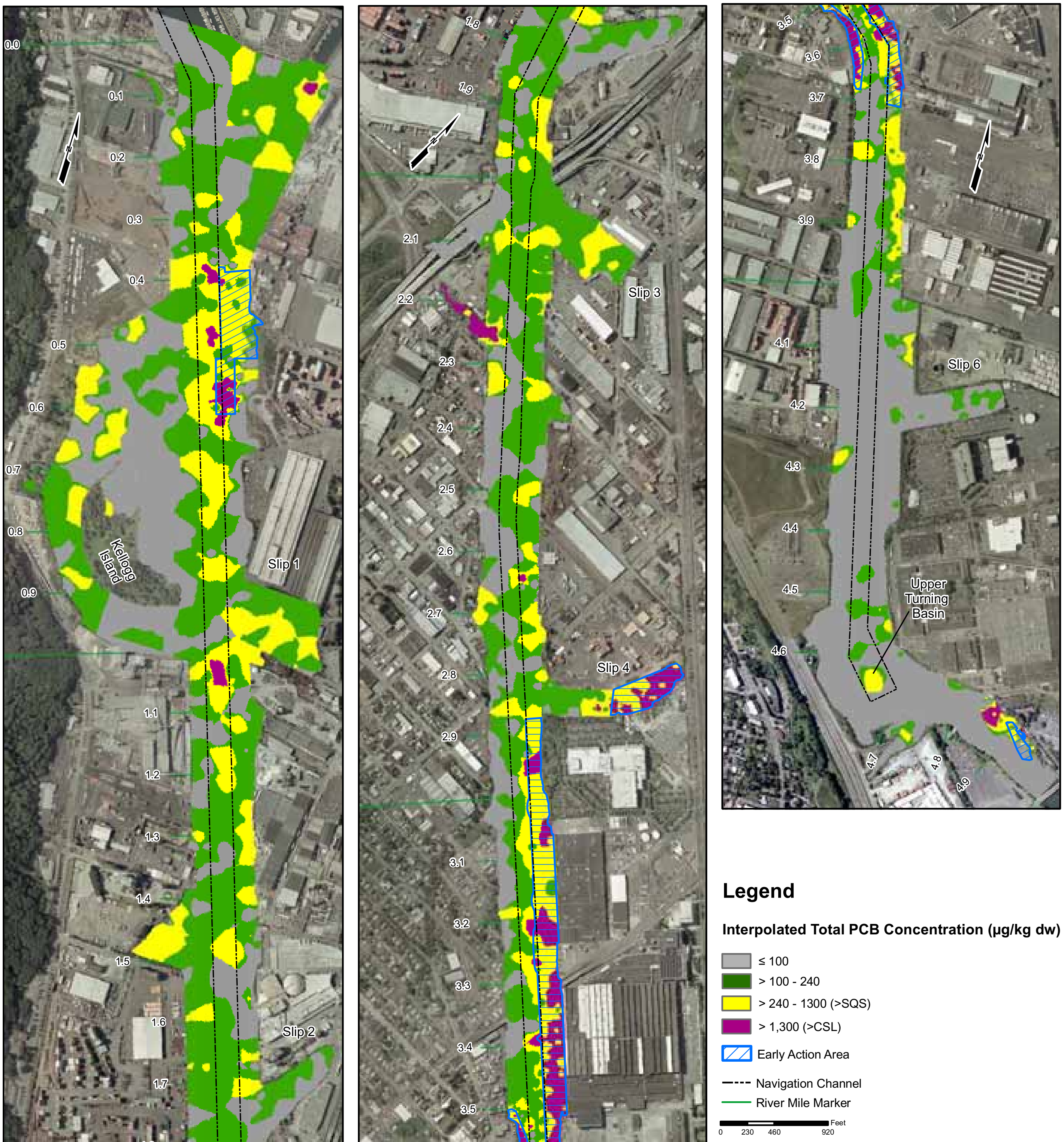
Summary of the Nature and Extent of Chemical Contamination

The RI (Windward 2010) collected and analyzed information about the nature and extent of chemical contamination, evaluated sediment transport processes, and assessed current conditions within the LDW, including risks to people and animals that use the LDW. The RI findings included the following:

- Chemicals in sediments were found at concentrations that could have adverse effects on the benthic community. Several chemicals were found in resident fish and shellfish tissue at concentrations that could result in increased cancer and non-cancer risks to people who rely on the LDW as a source of seafood.
- In general, higher concentrations of chemicals were detected in localized, fairly well defined areas separated by larger areas of the LDW with relatively low concentrations. Despite the widespread distribution of common contaminants, such as PCBs, locations with elevated concentrations were not always in the same areas, indicating that there may be multiple sources of these chemicals. In general, elevated carcinogenic polycyclic aromatic hydrocarbons (cPAH) concentrations were more dispersed than were those for PCBs and arsenic, suggesting more widespread sources for cPAHs. Except for a few areas with substantially higher concentrations, dioxins/furans were generally uniformly distributed in the LDW. Figure ES-2 shows the distribution of total PCBs within the LDW study area as an example of the uneven distribution pattern.

The Remedial Investigation included extensive sampling of sediments, fish, and shellfish.

Figure ES-2: Interpolated Total PCB Concentrations in Surface Sediments



Notes:
1. SQS values of 240 μg/kg dw based on conversion of 12 mg/kg oc to a dry weight value using 2% TOC.

Risk Summary

The baseline risk assessments conducted as part of the RI estimated risks to humans and ecological receptors (e.g., benthic invertebrates, fish, and wildlife), resulting from exposure to LDW contaminants in the absence of any cleanup measures. The risk assessments found the risks in the LDW to be high enough to warrant cleanup under both CERCLA and MTCA, summarized as follows:

- Chemicals contributing most to human health risks include PCBs, dioxins/furans, arsenic, and cPAHs. These are referred to as risk-driver chemicals for human health (Windward 2007b), based on the magnitude of their risk estimates and the relative percentage of their contributions to total human health risks.
- Risks to humans are mostly associated with consumption of resident fish[1], crabs, and clams. Reasonable maximum exposure (RME) seafood consumption rates (based on Tulalip Tribal and Asian and Pacific Islander seafood consumption rates) of resident fish, crabs, and clams result in a lifetime excess cancer risk that exceeds the CERCLA target risk range of 10^{-4} to10^{-6} and the MTCA lifetime excess cancer risk thresholds of one in one million (1×10^{-6}) for individual chemicals and one in one hundred thousand (1×10^{-5}) for all carcinogenic chemicals. Non-cancer risks (the potential for adverse effects other than cancer) above the CERCLA and MTCA risk thresholds were also associated with consumption of resident seafood.
- Lower risks to humans are associated with activities that involve direct contact with sediment, such as netfishing, tribal clamming, and beach play. The risks for these activities fall within the CERCLA target excess cancer risk range of 10^{-4} to 10^{-6}, but are sometimes above the MTCA risk threshold for individual chemicals.
- Forty-one chemicals were identified in the ecological risk assessment (Windward 2007a) as presenting a risk to benthic invertebrates because concentrations exceeded the Sediment Management Standards (SMS; WAC 173-204) sediment quality standards (SQS) in surface sediments at one or more locations.
- Chemical concentrations in surface sediments exceeded numerical standards in the SMS, indicating a potential for harmful effects to the benthic community. The SQS were exceeded in approximately 25% (109 acres) of the LDW study area. Within this 25% of the LDW, a higher likelihood for adverse effects was identified in approximately 7% of the LDW, where chemical concentrations or biological effects exceeded the cleanup screening levels (CSL) of the SMS, and 18% had chemical concentrations or minor biological effects falling between the SQS and CSL criteria. The remaining 75% of the LDW is considered not likely to have adverse effects on the benthic community.
- Ecological risks to crabs, fish, and most wildlife were relatively low, with the exception of river otters. River otters have a higher risk attributable to the presence of PCBs in their prey. PCBs were identified as a risk driver for river otters in the ecological risk assessment.

Photo courtesy Windward Environmental

Photo courtesy Don Wilson, Port of Seattle

The greatest risks to people are associated with eating resident fish, crabs, and clams. Lower risks are associated with activities that involve direct contact with sediment, such as tribal clamming, netfishing, and beach play. There are also risks for ecological receptors, such as benthic organisms and river otters.

1 The term resident fish does not include salmon. Salmon and other anadromous species use the LDW for only short time periods during their life cycle.

Risk Management Principles, Remedial Action Objectives (RAOs), and Preliminary Remediation Goals (PRGs)

A substantial body of research and guidance has been developed to address the management of risks from contaminated sediment. The regulatory agencies recognize that sediment cleanups are complex, difficult to predict, and often require an integrated approach for success. In response to these challenges and to lessons learned from other projects, EPA developed 11 sediment risk management principles (see text box). This FS has been prepared to be consistent with those principles.

Controlling sources of contaminants early, as noted, will be especially critical to the long-term success of any remedial action taken in the LDW. Ecology is leading a source control program to reduce sources of contaminants entering the LDW and the adequacy of source control will be determined prior to implementation of the selected remedial alternative.

Within the regulatory process itself, four remedial action objectives (RAOs) have been identified based on the results of the risk assessments. The RAOs describe what the sediment cleanup actions in the LDW should accomplish to address the risks identified in the risk assessments. The RAOs are:

- **RAO 1:** Reduce human health risks associated with the consumption of resident LDW fish and shellfish by reducing sediment and surface water concentrations of chemicals of concern to protective levels.
- **RAO 2:** Reduce human health risks associated with exposure to chemicals of concern through direct contact with sediments and incidental sediment ingestion by reducing sediment concentrations of chemicals of concern to protective levels.
- **RAO 3:** Reduce risks to benthic invertebrates by reducing sediment concentrations of chemicals of concern to comply with the Washington State SMS.
- **RAO 4:** Reduce risks to crabs, fish, birds, and mammals from exposure to chemicals of concern by reducing sediment and surface water concentrations of chemicals of concern to protective levels.

EPA Risk Management Principles Recommended for Contaminated Sediment Sites

1. Control sources early
2. Involve the community early and often
3. Coordinate with states, local governments, Indian tribes, and natural resource trustees
4. Develop and refine a conceptual site model that considers sediment stability
5. Use an iterative approach in a risk-based framework
6. Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models
7. Select site-specific, project-specific, and sediment-specific risk management approaches that will achieve risk-based goals
8. Ensure that sediment cleanup levels are clearly tied to risk management goals
9. Maximize the effectiveness of institutional controls and recognize their limitations
10. Design remedies to minimize short-term risks while achieving long-term protection
11. Monitor during and after sediment remediation to assess and document remedy effectiveness

Source: EPA 2002

Photo courtesy King County

Although the concentrations of four chemicals that drive human health risks are elevated within the LDW, they are also commonly found in urban environments at "background" concentrations that are not site-related. Therefore, it is not possible to entirely eliminate the risks associated with these chemicals.

Preliminary remediation goals (PRGs) were developed for each RAO; they represent the desired endpoint concentrations that are believed to provide adequate protection of human health and the environment. PRGs for a given risk-driver chemical may be applied to all locations (i.e., point-based), or applied as an average, either LDW-wide or over a specific exposure area. PRGs are preliminary at the FS stage and are finalized into cleanup levels in the decision document(s). Table ES-1 summarizes the PRGs for the risk-driver chemicals.

Both CERCLA and MTCA consider background chemical concentrations when formulating PRGs and cleanup levels. MTCA cleanup levels cannot be set at concentrations below natural background (WAC 173-340-705(6)). For those chemicals with risk-based concentrations below natural background concentrations, both CERCLA and MTCA allow the PRG to be set at background concentrations.

MTCA (WAC 173-340-200) defines natural background as the concentrations of hazardous substances that are consistently present in an environment that have not been influenced by localized human activities. Thus, under MTCA, a natural background concentration can be defined for man-made compounds even though they may not occur naturally (e.g., PCBs deposited by atmospheric deposition into an alpine lake). EPA and Ecology recognize that natural background concentrations for PCBs and dioxins/furans are unlikely to be met at the site and that long-term sediment concentrations will be governed primarily by sediment input from the Green/Duwamish River and the degree to which lateral inputs to the site are reduced as a result of on-going source control actions.

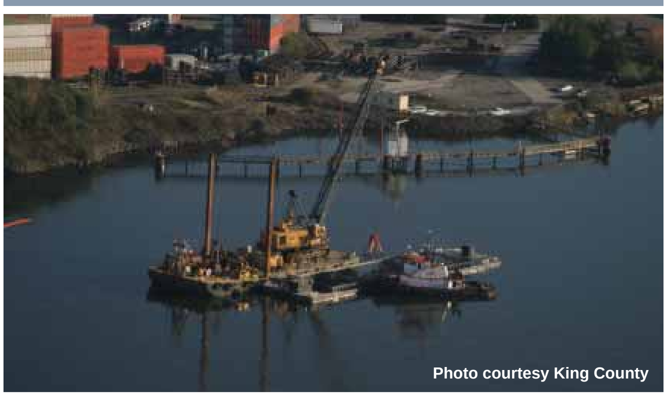


Photo courtesy King County

Cleanup actions have been completed at the Duwamish/Diagonal and Norfolk Early Action Areas and are in the design stage for three other Early Action Areas.

Definitions Used in this FS

- ***Cleanup level*** means the concentration of a hazardous substance in an environmental medium that is determined to be protective of human health and the environment under specified exposure conditions.
- ***Enhanced natural recovery (ENR)*** refers to the application of thin layers of clean granular material, typically sand, to a sediment area targeted for remediation. Essentially, ENR reduces the time to achieve RAOs over what is possible by relying solely on natural sediment deposition where burial is the principal recovery mechanism (EPA 2005b).
- ***Monitored natural recovery (MNR)*** is a passive remediation technology used where conditions support natural recovery. A monitoring program is instituted to assess if, and at what rate, risks are being reduced and whether progress is being made toward achieving the RAOs.
- ***Natural background*** is defined under MTCA as the concentrations of hazardous substances that are consistently present in an environment that has not been influenced by localized human activities (WAC 173-340-200).
- ***Preliminary remediation goals (PRGs)*** are specific desired endpoint concentrations or risk levels for each exposure pathway that are believed to provide adequate protection of human health and the environment, based on available site information (EPA 1997b).
- ***Remedial action objectives (RAOs)*** describe what the proposed remedial action is expected to accomplish (EPA 1999). They are narrative statements of the goals for protecting human health and the environment.
- ***Risk drivers*** are the chemicals of concern identified in the baseline risk assessments that present the principal risks; these are equivalent to indicator hazardous substances under MTCA.
- ***Remedial action levels (RALs)*** are chemical-specific sediment concentrations that might trigger the need for active remediation (e.g., dredging, capping, or enhanced natural recovery).

Table ES-1: Preliminary Remediation Goals for Total PCBs, Arsenic, cPAHs, and Dioxins/Furans in LDW Surface Sediment

Risk-Driver Chemical	Natural Background (UCL95)	Preliminary Remediation Goals (PRGs)				
		Spatial Scale of Exposure[a]	RAO 1: Human Seafood Consumption	RAO 2: Human Direct Contact	RAO 3: Benthic Organisms	RAO 4: Ecological (River Otter)
Total PCBs (µg/kg dw)	6.5	LDW-wide	background	1,300[b]	n/a	128
		Clamming	n/a	500	n/a	n/a
		Beach Play	n/a	1,700	n/a	n/a
		Point	n/a	n/a	SQS	n/a
Arsenic (mg/kg dw)	7.3	LDW-wide	tbd[c]	background[b]	n/a	n/a
		Clamming	n/a	background	n/a	n/a
		Beach Play	n/a	background	n/a	n/a
		Point	n/a	n/a	57	n/a
cPAHs (µg TEQ/kg dw)	8.9	LDW-wide	tbd[c]	380[b]	n/a	n/a
		Clamming	n/a	150[d]	n/a	n/a
		Beach Play	n/a	90	n/a	n/a
		Point	n/a	n/a	n/a[e]	n/a
Dioxins/Furans (ng TEQ /kg dw)	1.6	LDW-wide	background	37[b]	n/a	n/a
		Clamming	n/a	13	n/a	n/a
		Beach Play	n/a	28	n/a	n/a
		Point	n/a	n/a	n/a	n/a
Other SMS Chemicals	n/a	Point	n/a	n/a	SQS[f]	n/a

Notes:

a The spatial scale of site-wide exposure is RAO-specific. The statistical metric for LDW-wide, clamming, and beach play areas is the spatially weighted average concentration (SWAC) for the evaluation of alternatives (compliance monitoring will be based on upper confidence limit on the mean or SWAC).

b LDW-wide PRG based on netfishing scenario.

c There is no credible relationship, based on site data, relating cPAH or arsenic concentrations in sediment to concentrations in clam tissue. Cleanup goals are to be determined based on future investigations.

d PRG based on tribal clamming scenario.

e Low- and high-molecular weight PAHs are addressed by the SMS criteria. Criteria are set for both groupings and for individual compounds.

f Under the SMS, sediment cleanup standards are established on a site-specific basis within an allowable range. The SQS and CSL define this range. For this FS, the PRG has been set at the lowest end of this range (i.e., SQS). However, the final cleanup standard will be set in consideration of the net environmental effects, cost, and technical feasibility of different cleanup alternatives (WAC 173-204-570(4)).

Physical and Chemical Modeling

A sediment transport model (STM) was developed to evaluate long-term sediment transport processes in the LDW. The model findings included the following:

- It is estimated that an average of more than 100,000 metric tons of sediment are deposited within the LDW each year. More than 99% of the new sediment originates in the Green/Duwamish River, upstream of the LDW; less than 1% originates from storm drains, CSOs, and streams that discharge directly into the LDW. These newly deposited sediments are mixed with the existing surface sediments over much of the area through bioturbation and resuspension and redeposition processes associated with disturbances, such as ship-induced bed scour, high flow events, and dredging.
- Based on the STM, erosion of the sediment bed by river flow is limited, even during high-flow events. Net erosion is predicted to occur over about 18% of the LDW bed area during high-flow events. Most bed erosion is less than 10 centimeters (cm) in depth and maximum estimated net erosion depths are 22 cm or less. The majority of eroded sediment resettles within the LDW. Vessels may also cause localized scour during intense maneuvering, but model predictions suggest that such scour is limited to a depth of about 30-45 cm. The effects of ship-induced bed scour are incorporated into the present structure of the LDW sediment bed because ship movement has been occurring since the LDW was created in the early 20th century.
- To evaluate changes in sediment chemical concentrations over time (considering both natural recovery and recontamination potential), STM results were combined with estimates of chemical concentrations on solids entering the LDW from upstream, as well as from storm drains, CSOs, and small streams discharging directly into the LDW. This analysis included both quantitative modeling and analyses of multiple lines of empirical evidence, and yielded the following results:
  - The physical conceptual site model of the LDW as a net depositional environment is supported by modeling and both physical and chemical lines of evidence from sediment core profiles. Empirically derived net sedimentation rates average 1 to 3 cm/yr in most of the subtidal areas, and > 70 cm/yr in the Upper Turning Basin, which acts as a natural sediment trap for incoming sediment. Exceptions to the conceptual site model caused by location-specific features were also observed (i.e., vessel scour, outfalls, structures).
  - Chemical concentrations in LDW surface sediments are expected to be reduced as a result of remedial actions and then to gradually lower over a period of decades to concentrations close to those found in upstream sediment and suspended solids. Localized areas near large storm drains, CSOs, or other upland sources may not recover as quickly, or may have persistently elevated concentrations of some chemicals, even after upland source control actions. Areas that either have low sedimentation rates or are regularly physically disturbed also may not recover.
  - There is uncertainty in the model predictions of changes in sediment chemistry over time. The two largest sources of uncertainty in the physical and chemical model predictions are: 1) the rate of net sedimentation/burial from incoming sediment loads, and 2) chemical concentrations in incoming sediments. These uncertainties were evaluated and factored into the development and comparative analyses of alternatives.


Photo courtesy King County

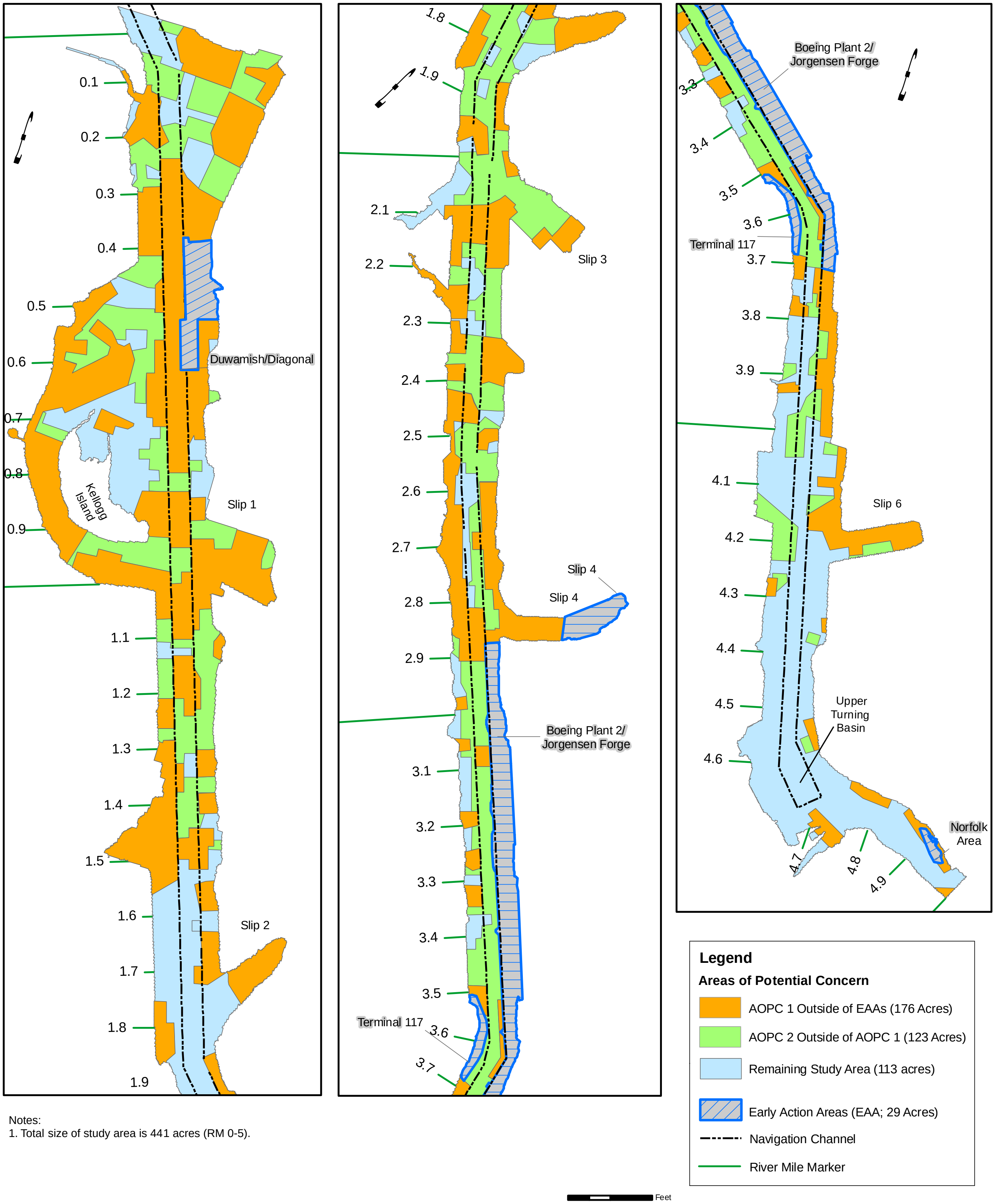
Areas of Potential Concern

A first step in alternative development was to map Areas of Potential Concern (AOPCs) that present unacceptable risks to human health and the environment in surface and subsurface sediments and may require remediation. Figure ES-3 shows AOPC 1 and AOPC 2, the two cleanup areas within the LDW. AOPC 1 includes areas above the SQS and areas with unacceptably high direct contact human health risks. AOPC 2 includes AOPC 1 plus additional areas with total PCB concentrations above 100 µg/kg dw.

The available baseline surface sediment data used to delineate the AOPCs span approximately 20 years. For this reason, uncertainty exists regarding existing chemical concentrations in the LDW. Some areas may have already recovered naturally. Therefore, using the total area that exceeds risk-based threshold concentrations to develop the AOPCs is considered to be conservative. Areas requiring cleanup will be refined through additional sampling during remedial design.

The effects of ship traffic on sediment transport were evaluated in this Feasibility Study.

Figure ES-3: Early Action Areas and Areas of Potential Concern



Notes:
1. Total size of study area is 441 acres (RM 0-5).

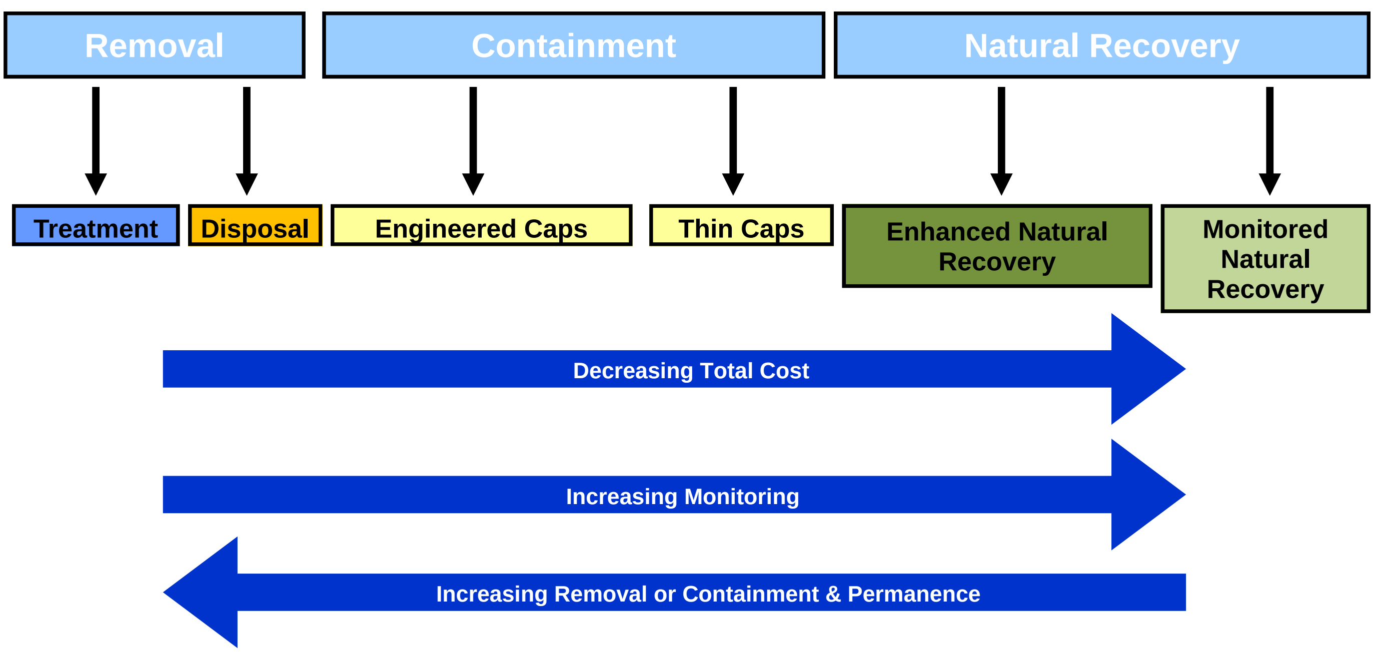
Evaluation and Screening of Technologies

Several technologies are applicable for remediating contaminated sediments in the LDW, including a range of active technologies that remove or isolate contaminated sediment, and passive technologies that monitor recovery and exposure to contaminated sediment left in place (Figure ES-4). These include:

- Physical removal (e.g., dredging) of contaminated sediments. Options to process the dredged material include:
  – Treatment
  – On-site and off-site disposal (e.g., in a permitted landfill)
- Containment (isolation or reactive capping) of contaminated sediments, typically using engineered layers of sand, gravel, or rock
- Enhanced natural recovery (ENR) that uses a thin-layer placement of materials (e.g., sand) to enhance natural recovery processes
- Monitored natural recovery (MNR) that relies on natural processes of sedimentation to reduce surface sediment chemical concentrations
- Monitoring sediments, biota, and water before, during, and after active cleanup in the LDW
- Contingencies for additional active cleanup, incorporated in the FS if monitoring shows cleanup levels are not being met as expected
- Institutional controls, such as advisories to limit consumption of resident seafood from the LDW or restrictions on activities such as dredging or anchoring in specified areas

The LDW-wide remedial alternatives selected for evaluation in this FS include various combinations of these response actions. For each general response action, a number of different technologies can be used. The FS selected representative technologies for evaluation, but other similar technologies discussed herein may be considered during remedial design. These technologies have been widely used in the Puget Sound region and nationally at other contaminated sediment sites. Figure ES-4 illustrates the technologies selected for this FS for managing contaminated sediments.

Figure ES-4: Technologies for Management of Contaminated Sediments



Various technologies are available to clean up the LDW. Combinations of removal, containment, and natural recovery are evaluated as remedial alternatives.

Development of Remedial Alternatives and Remedial Action Levels

The remedial alternatives evaluated in this FS use a combination of active remediation and passive remediation technologies to achieve the RAOs and PRGs over various time frames. Each alternative differs in the remedial action levels (RALs) applied, the rate at which sediment chemical concentrations are reduced, the type and scale of technologies used, and the relative uncertainty associated with outcomes derived by model predictions of natural recovery versus active cleanup. The RALs are chemical-specific sediment concentrations that trigger the need for active remediation (action is required when a location exceeds a RAL). RALs are also used as compliance targets to verify that active remediation is complete, or successful. By selecting different RALs, the alternatives reflect varying amounts of active (i.e., dredge, isolation cap, ENR) versus passive technologies. This in turn affects the duration of construction activities, the extent to which active technologies rather than natural recovery are relied upon to reach PRGs, and how much time it is likely to take to achieve the RAOs. RALs for each risk-driver chemical were developed with the understanding that remediation of these risk-driver chemicals will also address other chemicals of concern.

In developing alternatives, the size of the active remedial footprint was determined based on RAL exceedances. Technologies were then assigned to specific areas based on localized conditions, including sediment transport and chemical characteristics, navigation uses and depth requirements, habitat considerations, and localized potential for natural recovery. These technology assignments are considered preliminary and will be refined in remedial design.

In addition to a no further action alternative (Alternative 1), 11 remedial alternatives have been developed to bracket the potential remedial design and implementation options, and a range of RALs (half the alternatives have the same RALs, but use different technologies). Some alternatives focus on removal (R) of sediments from areas where chemical concentrations exceed the RALs, while other alternatives focus on a combination (C) of removal, containment, and ENR technologies for managing those areas. Each successive alternative builds on the active footprint of the previous alternative, so that the alternatives get incrementally larger, with active remediation growing from 29 to 328 acres. In addition, options for on-site disposal or treatment of dredged materials are included in Alternatives 2 and 5, respectively, to provide perspective on how these treatment options could affect costs, schedule, and performance. The remedial alternatives and the goals of each are summarized on the following pages.

Greater sediment removal through dredging means greater permanence, but at a higher cost and over a longer period than other technologies. Also, for people and wildlife that eat resident seafood from the LDW, risks will likely remain high throughout the dredging period under any alternative. Consumption advisories can help manage these increased risks to people, but not wildlife.

Alternative 1 – No Further Action

Alternative 1 assumes cleanup of only the EAAs (29 acres). No further management would occur outside the EAAs. This alternative is not formulated with specific risk reduction goals in mind. It provides a baseline for comparison with the other remedial alternatives and is required by CERCLA. Two of the EAAs have been cleaned up and the other three are in the final planning stages; it is assumed that cleanup of the remaining EAAs will be completed, regardless of which of the remedial alternatives is selected for the remainder of the LDW.

Alternatives 2R and 2R-CAD

Alternative 2 RALs were selected to target hot spots in the LDW with a total area of 30 acres. Alternative 2R includes upland disposal of dredged sediments, while Alternative 2R-CAD includes on-site disposal in a contained aquatic disposal (CAD) facility. Both alternatives are predicted to achieve RAO 1 using active cleanup, MNR, and institutional controls,[2] with maximum contaminant reduction predicted to occur within 24 years of initiating the site cleanup activities.[3] They are also predicted to achieve RAOs 2, 3, and 4 within 19 years. The time frames for achieving the cleanup objectives include certain assumptions regarding natural recovery. These alternatives rely on natural recovery to a greater extent than do the other alternatives, and therefore have the greatest uncertainty with respect to the recovery time frames. They also include contingencies for additional cleanup if the site is not on track to meet its cleanup objectives within 10 years after cleanup (19 years after implementation of the site cleanup).

Alternatives 3C and 3R

Alternative 3 RALs are more stringent (lower) than Alternative 2 RALs and also include RALs specific to the intertidal areas. Alternatives 3C and 3R differ from Alternative 2R and 2R-CAD by actively remediating 57 rather than 30 acres. Alternatives 3C and 3R are predicted to achieve RAO 1 using active cleanup, MNR, and institutional controls, with maximum contaminant reduction predicted to occur within 24 to 26 years. They are predicted to achieve RAOs 2 and 4 immediately following construction (9 and 11 years from implementation of site cleanup) and to achieve RAO 3 within 5 years following construction (14 and 16 years respectively). They also include contingencies for additional cleanup if the site is not on track to meet its cleanup objectives within 10 years after cleanup (24 or 26 years after implementation of the site cleanup).

Alternatives 4C and 4R

Alternative 4 RALs are lower than those for Alternative 3. Alternatives 4C and 4R differ from Alternatives 3C and 3R by actively remediating 114 rather than 57 acres. Alternatives 4C and 4R are predicted to achieve RAO 1 using increased reliance on active cleanup, while also using MNR and institutional controls, with maximum contaminant reduction predicted to occur within 10 years after construction (22 and 18 years following implementation of site cleanup). They are predicted to achieve RAOs 2, 3, and 4 immediately following construction (12 and 18 years

Quick Reference: Remedial Action Objectives (RAOs)

- ***RAO 1:*** Reduce human health risks associated with the consumption of resident LDW fish and shellfish by reducing sediment and surface water concentrations of chemicals of concern to protective levels.
- ***RAO 2:*** Reduce human health risks associated with exposure to chemicals of concern through direct contact with sediments and incidental sediment ingestion by reducing sediment concentrations of chemicals of concern to protective levels.
- ***RAO 3:*** Reduce risks to benthic invertebrates by reducing sediment concentrations of chemicals of concern to comply with the Washington State SMS.
- ***RAO 4:*** Reduce risks to crabs, fish, birds, and mammals from exposure to chemicals of concern by reducing sediment and surface water concentrations of contaminants of concern to protective levels.

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2 Institutional controls may include seafood consumption advisories and other public outreach designed to increase seafood consumers' awareness of risks and to reduce unacceptable exposures.

3 Site cleanup begins after the issuance of decision documents for the LDW and includes initial remedial design activities, baseline monitoring, and completion of the EAAs (all of which is expected to require up to 5 years). After this time, construction of the selected alternative would begin. The total implementation time for each alternative includes these first five years and the time up to the completion of construction.

following the implementation of site cleanup). They also include contingencies for additional cleanup if the site is not on track to meet its cleanup objectives within 10 years after cleanup (22 or 28 years after implementation of the site cleanup).

Alternatives 5C, 5R, and 5R-Treatment

The Alternative 5 RALs are more stringent (lower) than those for Alternative 4; RALs for PCBs and other SMS chemicals are based on the SQS. RALs for the other risk drivers are the same as for Alternatives 4R and 4C. Alternatives 5C, 5R and 5R-Treatment differ from Alternatives 4C and 4R by actively remediating 157 rather than 114 acres. Alternatives 5C, 5R, and 5R-Treatment are predicted to achieve RAO 1 using increased reliance on active cleanup. Maximum contaminant reduction is predicted to occur within 5 years after construction for 5C (18 following implementation of site cleanup) and immediately following construction for 5R and 5R-Treatment (24 years). They are predicted to achieve RAOs 2, 3, and 4 immediately following construction (13 and 24 years following implementation of site cleanup). Alternative 5R specifies removal and upland disposal of sediment from the actively remediated areas, while Alternative 5R-Treatment specifies removal with soil washing or a similar technology for treatment of sediment from these areas, which may reduce the volume of contaminated sediment requiring upland disposal. The treatment component could also be included in any of the other alternatives.

Alternatives 6C and 6R

The Alternative 6 RALs are the most stringent RALs considered in the FS for PCBs, arsenic, and dioxins/furans. These RALs are a best professional judgment of what is estimated to be the lower end of the practicable range for RALs considering available information on the potential for recontamination and resuspension and continued sediment input from the Green/Duwamish River and the LDW drainage basin. Alternatives 6C and 6R rely solely on active remediation to achieve cleanup goals. They have the largest cleanup footprint of all alternatives, requiring active remediation of 299 rather than 157 acres for 5C, 5R, and 5R-Treatment. Alternative 6 RALs are designed to achieve RAO 1 using active cleanup, with maximum contaminant reduction expected to occur immediately following construction (23 and 43 years after implementation of site cleanup). Additional reduction in seafood consumption exposure is provided by institutional controls. RAOs 2, 3, and 4 are also achieved immediately following construction.

Figure ES-5 presents the remedial alternatives, defines the relative numbers of acres managed through active remediation, MNR, and institutional controls, and shows the estimated time and costs to achieve the RAOs. Table ES-2 presents the RALs and the outcomes that each remedial alternative is predicted to achieve.

Removal with upland disposal would involve transporting the dredged sediment by barge to a staging area where the sediment would be loaded into rail cars for transport to an off-site regional landfill.

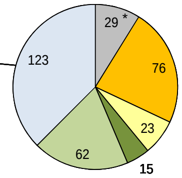
Figure ES-5: Summary of Alternatives

LEGEND

Remedial Alternative

Acres per technology

Comparative analysis



	EAAs
	Dredge and Partial Dredge and Cap
	Cap
	ENR
	MNR(10), MNR(20), and VM
	ICs and Site-wide Monitoring

Construction Time
Dredging Volume
Time to Achieve RAOs (Time to Achieve Predicted Long-term Concentrations, if different)
Base Case Costs
*Range of Costs

Notes:

1) Acreages for early action areas (EAAs) are shown here for completeness; they are common to all the alternatives (marked with asterisk). Decisions on those cleanups have been made and are not part of the decision process represented by this FS. EAA in-water work is estimated at $66 million. Substantial additional costs are expected for upland cleanups and source control. For example, at T-117 the in-water costs are approximately $6 million, and the upland costs are approximately $27 million. The EAA costs and the costs of upland cleanup and source control are not included in cost estimates shown for Alternatives 2 through 6.

2) Two cost estimates are shown for each alternative. The first represents a single-point estimate for simply comparing alternatives. The second, a range, reflects high and low sensitivity of costs to actual field design conditions. Actual costs are estimated to fall within the ranges. Costs are rounded to the nearest $10 million.

3) The pie represents 328 acres, i.e., the area where alternatives differ in the types of technologies evaluated. The total area of the FS study area 441 acres. The costs of monitoring and maintaining institutional controls over the entire LDW study area are included in the remedial alternative costs.

4) MNR(10) applies to Alternatives 2 and 4 where the goal is to reach the CSL or SQS, respectively, within 10 years after active remediation. MNR(20) applies to Alternatives 2 and 3, where the goal is to achieve the SQS over a time frame longer than 10 years.

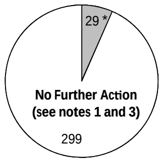
5) Total time is for achievement of all RAOs.

6) Long-term model predicted range of concentrations applies to RAO 1.

CSL = cleanup screening level; cy = cubic yards; EAAs = early action areas;
ENR = enhanced natural recovery; ICs = institutional controls;
MNR = monitored natural recovery; n/a = not applicable;
RAL = remedial action level; RAO = remedial action objective
SQS = sediment quality standard; VM = verification monitoring

Alternative 1
Actively Remediated Area: 29 acres

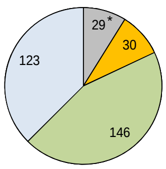
Alternative 1



n/a
n/a
n/a
See note 1

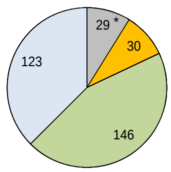
Alternative 2
Actively Remediated Area: 59 acres*

Alternative 2 Removal with CAD



4 years
620,000 cy
19 years (24 years)
$210 Million
$93 to $330 Million

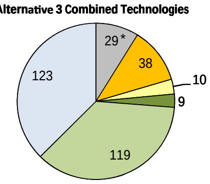
Alternative 2 Removal Emphasis



4 years
620,000 cy
19 years (24 years)
$230 Million
$90 to $360 Million

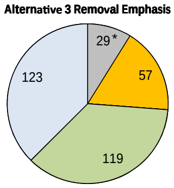
Alternative 3
Actively Remediated Area: 86 acres*

Alternative 3 Combined Technologies



4 years
570,000 cy
14 years (24 years)
$220 Million
$120 to $360 Million

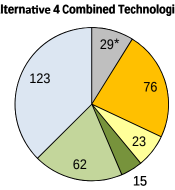
Alternative 3 Removal Emphasis



6 years
790,000 cy
16 years (26 years)
$290 Million
$190 to $460 Million

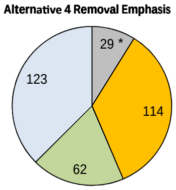
Alternative 4
Actively Remediated Area: 143 acres*

Alternative 4 Combined Technologies



7 years
740,000 cy
12 years (22 years)
$290 Million
$210 to $410 Million

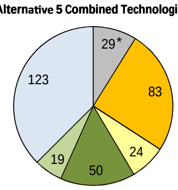
Alternative 4 Removal Emphasis



13 years
1,200,000 cy
18 years
$440 Million
$350 to $630 Million

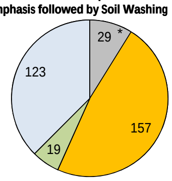
Alternative 5
Actively Remediated Area: 186 acres*

Alternative 5 Combined Technologies



8 years
770,000 cy
13 years (18 years)
$310 Million
$230 to $450 Million

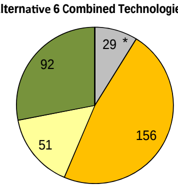
Alternative 5 Removal Emphasis/5 Removal Emphasis followed by Soil Washing



19 years
1,500,000 cy
24 years
$550 Million / $600 Million
$460 to $940 Million

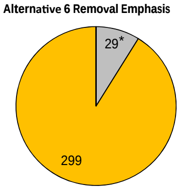
Alternative 6
Actively Remediated Area: 328 acres*

Alternative 6 Combined Technologies



18 years
1,700,000 cy
23 years
$650 Million
$450 to $820 Million

Alternative 6 Removal Emphasis



38 years
3,600,000 cy
43 years
$1,350 Million
$970 to $1,500 Million

Table ES-2: Remedial Alternatives, Remedial Action Levels, and Long-term Model Predicted Outcomes

Remedial Alternative and Implementation Period[a]	Remedial Action Levels	Remedial Alternatives and Predicted Outcomes RAO 1: Human Health – Seafood Consumption for PCBs[b] (see Tables 9-5 and 9-6a)	RAO 2: Human Health – Direct Contact[c] (see Tables 9-3, 9-7, and M-8)	RAO 3: Ecological Health – Benthic[d] (see Table 9-2b)	RAO 4: Ecological Health – Seafood Consumption: River Otter (see Table 9-6b)
Alternative 1 No Further Action after removal or capping of EAAs (5 years)	n/a	Incremental risk reduction.	Incremental direct contact risk reduction.	Incremental reduction in CSL and SQS exceedances.	Incremental HQ reduction.
Alternative 2 – removal emphasis with upland disposal/MNR (9 years) Alternative 2 with CAD – dredge emphasis with contained aquatic disposal/MNR (9 years)	**Total PCBs:** 1,300 to 2,200 µg/kg dw **cPAHs:** 5,500 µg TEQ/kg dw **Dioxins/Furans:** 50 ng TEQ/kg dw **Arsenic:** 93 mg/kg dw **SMS chemicals:** achieve CSL within 10 years	Immediately following implementation (9 yrs): Predicted to achieve 10^{-4} magnitude risk for adult tribal, child tribal and adult API. Seafood consumption exposures further reduced through a multi-layered program of advisories, outreach, and education. River-wide recovery processes monitored to assess long-term human health risk reduction. 5 years post-implementation (14 yrs): Predicted to achieve 10^{-5} magnitude risk for child tribal. 15 years post-implementation (24 yrs): All four risk drivers predicted to reach modeled long-term concentration ranges site-wide. Modeled long-term non cancer risk; HQ >1	Immediately following implementation (9 yrs): Predicted to achieve 1×10^{-5} cumulative risk and HQ <1 for netfishing (site-wide), tribal clamming, and assumed beach play areas (each beach); achieves 1×10^{-6} risk for dioxins/furans and total PCBs in all areas. Predicted to achieve 10^{-6} magnitude risk for arsenic for netfishing (site-wide) and beach play and 10^{-5} magnitude risk for tribal clamming. Predicted to achieve 1×10^{-6} risk for cPAHs netfishing (site-wide) and tribal clamming and 10^{-6} magnitude risk for beach play. Predicted to achieve MTCA natural background for arsenic for all exposure areas. 15 years post-implementation (24 yrs): Predicted to achieve MTCA unrestricted cleanup level for cPAHs for all beaches except Beach 3.	Immediately following implementation (9 yrs): predicted to achieve CSL 10 years post-implementation (19 yrs): predicted to achieve SQS. Note: Recovery Category 1 areas subject to natural recovery in Alternative 2; therefore, modeled times may be under-predicted.	Immediately following implementation (9 yrs): Predicted to achieve HQ <1.
Alternative 3 removal emphasis (3R) – dredge with upland disposal/MNR (11 years) Alternative 3 combined technology (3C) – ENR/cap/MNR where appropriate, otherwise dredge with upland disposal (9 years)	**Total PCBs:** 1,300 µg/kg dw **cPAHs:** 3,800 µg TEQ/kg dw; 900 µg TEQ/kg dw (intertidal) **Dioxins/Furans:** 35 ng TEQ/kg dw; 28 ng TEQ/kg dw (intertidal) **Arsenic:** 93 mg/kg dw; 28 mg/kg dw (intertidal) **SMS chemicals:** CSL toxicity or chemistry	Immediately following implementation (9 yrs 3C; 11 yrs 3R): Predicted to achieve 10^{-4} magnitude risk for adult tribal, child tribal and adult API. Seafood consumption exposures further reduced through a multi-layered program of advisories, outreach, and education. River-wide recovery processes monitored to assess long-term human health risk reduction. 5 years post-implementation (14 yrs 3C; 16 yrs 3R): Predicted to achieve 10^{-5} magnitude risk for child tribal. 15 years post-implementation (24 yrs 3C; 26 yrs 3R): All four risk drivers predicted to reach modeled long-term concentration ranges site-wide. Modeled long-term non cancer risk; HQ >1	Immediately following implementation (9 yrs 3C; 11 yrs 3R): Predicted to achieve 1×10^{-5} cumulative risk and HQ <1 for netfishing, tribal clamming, and assumed beach play areas (each beach); achieves 1×10^{-6} risk for dioxins/furans and total PCBs in all areas. Predicted to achieve 10^{-6} magnitude risk for arsenic for netfishing (site-wide) and beach play and 10^{-5} magnitude risk for tribal clamming. Predicted to achieve 1×10^{-6} risk for cPAHs netfishing (site-wide) and tribal clamming and 10^{-6} magnitude risk for beach play. Predicted to achieve MTCA natural background for arsenic for all exposure areas. 5 years post-implementation (14 yrs 3C; 16 yrs 3R): Predicted to achieve MTCA unrestricted cleanup level for cPAHs for all beaches except Beach 3.	Immediately following implementation (9 yrs 3C; 11 yrs 3R): Predicted to achieve CSL 5 years post-implementation (14 yrs 3C; 16 yrs 3R): Predicted to achieve SQS.	Immediately following implementation (9 yrs 3C; 11 yrs 3R): Predicted to achieve HQ <1.
Alternative 4 removal emphasis (4R) – dredge with upland disposal/MNR (18 years) Alternative 4 combined technology (4C) – ENR/cap/MNR where appropriate, otherwise dredge with upland disposal (12 years)	**Total PCBs:** 240 to 700 µg/kg dw **cPAHs:** 1,000 µg TEQ/kg dw; 900 µg TEQ/kg dw (intertidal) **Dioxins/Furans:** 25 ng TEQ/kg dw **Arsenic:** 57 mg/kg dw; 28 mg/kg dw (intertidal) **SMS chemicals:** achieve SQS within 10 years	Immediately following implementation (12 yrs 4C; 18 yrs 4R): predicted to achieve 10^{-4} risk magnitude for adult tribal, child tribal and adult API. Seafood consumption exposures further reduced through a multi-layered program of advisories, outreach, and education. River-wide recovery processes monitored to assess long-term human health risk reduction. All four risk drivers predicted to reach modeled long-term concentration ranges site-wide by Alternative 4R. 5 years post-implementation (17 yrs 4C; 23 yrs 4R): Predicted to achieve 10^{-5} magnitude risk for child tribal. 10 years post-implementation (22 yrs 4C): All four risk drivers predicted to reach modeled long-term concentration ranges site-wide by Alternative 4C. Modeled long-term non cancer risk; HQ >1	Immediately following implementation (12 yrs 4C; 18 yrs 4R): Predicted to achieve 1×10^{-5} cumulative risk and HQ <1 for netfishing, tribal clamming, and assumed beach play areas (each beach); achieves 1×10^{-6} risk for dioxins/furans and total PCBs in all areas. Predicted to achieve 10^{-6} magnitude risk for arsenic for netfishing (site-wide) and beach play and 10^{-5} magnitude risk for tribal clamming. Predicted to achieve 1×10^{-6} risk for cPAHs netfishing (site-wide) and tribal clamming and 10^{-6} magnitude risk for beach play. Predicted to achieve MTCA natural background for arsenic for all exposure areas. Predicted to achieve MTCA unrestricted cleanup level for cPAHs for all beaches except Beach 3.	Immediately following implementation (12 yrs 4C; 18 yrs 4R): Predicted to achieve SQS.	Immediately following implementation (12 yrs 4C; 18 yrs 4R): Predicted to achieve HQ <1.

Table ES-2 (continued): Remedial Alternatives, Remedial Action Levels, and Long-term Model Predicted Outcomes

Remedial Alternative and Implementation Period[a]	Remedial Action Levels	Remedial Alternatives and Predicted Outcomes			
		RAO 1: Human Health – Seafood Consumption for PCBs[b] (see Tables 9-5 and 9-6a)	RAO 2: Human Health – Direct Contact[c] (see Tables 9-3, 9-7, and M-8)	RAO 3: Ecological Health – Benthic[d] (see Table 9-2b)	RAO 4: Ecological Health – Seafood Consumption: River Otter (see Table 9-6b)
Alternative 5 removal emphasis (5R) – dredge with upland disposal (24 years) Alternative 5 removal with treatment (5RT) – dredge with soil washing treatment and disposal/ re-use[d] (24 years) Alternative 5 combined technology (5C) – ENR/ cap where appropriate, otherwise dredge with upland disposal (13 years)	**Total PCBs:** 240 µg/kg dw **cPAH s:** 1,000 µg TEQ/kg dw; 900 µg TEQ/kg dw (intertidal) **Dioxins/Furans:** 25 ng TEQ/kg dw **Arsenic:** 57 mg/kg dw; 28 mg/kg dw (intertidal) **SMS chemicals:** SQS toxicity or chemistry	Immediately following implementation (13 yrs 5C; 24 yrs 5R): Predicted to achieve 10^{-4} magnitude risk for adult tribal and adult API, and 10^{-5} magnitude risk for child tribal. Seafood consumption exposures would be further reduced through a multi-layered program of advisories, outreach, and education. River-wide recovery processes would be monitored to assess long-term human health risk reduction. All four risk drivers predicted to reach modeled long-term concentration ranges site-wide by Alternative 5R. 5 years post-implementation (18 yrs 5C): All four risk drivers predicted to reach modeled long-term concentration ranges site-wide by Alternative 5C. Modeled long-term non cancer risk; HQ >1	Immediately following implementation (13 yrs 5C; 24 yrs 5R): Predicted to achieve 1×10^{-5} cumulative risk and HQ<1 for netfishing, tribal clamming, and assumed beach play areas (each beach); achieves 1×10^{-6} risk for dioxins/furans and total PCBs in all areas. Predicted to achieve 10^{-6} magnitude risk for arsenic for netfishing (site-wide) and beach play and 10^{-5} magnitude risk for tribal clamming. Predicted to achieve 1×10^{-6} risk for cPAHs netfishing (site-wide) and tribal clamming and 10^{-6} magnitude risk for beach play. Predicted to achieve MTCA natural background for arsenic for all exposure areas. Predicted to achieve MTCA unrestricted cleanup level for cPAHs for all beaches except Beach 3.	Immediately following implementation (13 yrs 5C; 24 yrs 5R): Predicted to achieve SQS.	Immediately following implementation (13 yrs 5C; 24 yrs 5R): Predicted to achieve HQ<1.
Alternative 6 removal emphasis (6R) – dredge with upland disposal (43 years) Alternative 6 combined technology (6C) – ENR/ cap where appropriate, otherwise dredge with upland disposal (23 years)	**Total PCBs:** 100 µg/kg dw **cPAHs:** 1,000 µg TEQ/kg dw; 900 µg TEQ/kg dw (intertidal) **Dioxins/Furans:** 15 ng TEQ/kg dw **Arsenic:** 15 mg/kg dw **SMS chemicals:** SQS toxicity or chemistry	Immediately following implementation (23 yrs 6C; 43 yrs 6R): Predicted to achieve 10^{-4} magnitude risk for adult tribal and adult API and 10^{-5} magnitude risk for child tribal. All four risk drivers predicted to reach modeled long-term concentration ranges site-wide. Seafood consumption exposures further reduced through a multi-layered program of advisories, outreach, and education. River-wide recovery processes monitored to assess long-term human health risk reduction. Modeled long-term non cancer risk; HQ >1	Immediately following implementation (23 yrs 6C; 43 yrs 6R): achieve 1×10^{-5} cumulative risk and HQ <1 for netfishing, tribal clamming, and assumed beach play areas (each beach) achieves 1×10^{-6} risk for dioxins/furans and total PCBs in all areas. Predicted to achieve 10^{-6} magnitude risk for arsenic for netfishing (site-wide) and beach play and 10^{-5} magnitude risk for tribal clamming. Predicted to achieve 1×10^{-6} risk for cPAHs netfishing (site-wide) and tribal clamming and 10^{-6} magnitude risk for beach play. Predicted to achieve MTCA natural background for arsenic for all exposure areas. Predicted to achieve MTCA unrestricted cleanup level for cPAHs for all beaches except Beach 3.	Immediately following implementation (23 yrs 6C; 43 yrs 6R): Predicted to achieve SQS.	Immediately following implementation (23 yrs 6C; 43 yrs 6R): Predicted to achieve HQ<1.

Notes:

a Alternatives 2 through 6 include institutional controls and site-wide monitoring. Implementation period = 5 years from remedy decision documents plus construction period (see Figure 9-2).

b Only risks from total PCBs are discussed for human health seafood consumption because sediment to tissue relationships could not be developed for the other three risk drivers. No alternative can meet the natural background PRGs for total PCBs (2 µg/kg dw) or dioxins/furans (2 ng TEQ/ kg dw). Model-predicted long-term (25 years) and site-wide outcomes for all four risk-driver chemicals and all alternatives, excluding Alternative 1, are approximately: 40 to 50 µg/kg dw (total PCBs), 9 to 10 mg/kg dw (arsenic), 100 to 110 mg TEQ/kg dw (cPAHs), and 4 to 5 ng TEQ/kg dw (dioxins/furans).

c All alternatives are predicted to achieve the cumulative direct contact risk of 1×10^{-5} in beach play areas. All beaches are below the 90th percentile (WAC 173-340-709 (3)) but above the UCL95 of the natural background dataset for arsenic. All beaches except Beach 3 are below a concentration of 140 µg TEQ/kg dw (MTCA Method B unrestricted soil direct contact; WAC 173-340-740 (3)) and thereby comply with the MTCA ARAR. The BCM model output for Beach 3 is influenced by a lateral source.

d Reduction of SQS and CSL exceedances sufficient to meet the RAO 3 criteria is dependent on adequate source control and natural recovery during construction. Achievement may take a few years longer if these two factors are not considered. Localized recontamination is expected (see Appendix J) but not accounted for in the results presented in this table.

Detailed Evaluation and Comparative Analysis of Remedial Alternatives

The remedial alternatives were evaluated using both CERCLA and MTCA criteria, which are similar (see Table ES-3). CERCLA has nine criteria, (two threshold criteria, five balancing criteria, and two modifying criteria). The two CERCLA threshold criteria, which must be met before the others can be considered, are protection of human health and the environment and compliance with applicable or relevant and appropriate requirements (ARARs) of pertinent environmental laws and regulations. The five balancing criteria are:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

These threshold and balancing criteria are evaluated as part of the FS. The last two criteria, state/tribal and community acceptance, are evaluated by the EPA after the FS is completed and include consideration of formal public comments on the proposed plan. Alternative 1 was analyzed in the detailed and comparative analyses as the CERCLA baseline alternative; it provides the least protection of human health and the environment. It does not achieve any of the RAOs because it does not include adequate engineering or institutional controls, or provide for monitoring. Because it is the no action alternative, Alternative 1 is not discussed further in this summary of the comparative analyses.

Because MTCA has similar requirements to CERCLA, the MTCA analysis of alternatives yielded similar results. The MTCA criteria are listed in Table ES-3 and contrasted to the CERCLA criteria in Section 11. It is assumed that the EAAs will be completed regardless of which of the remedial alternatives is selected for the remainder of the LDW.

Figure ES-6 summarizes the predicted time required to achieve the RAOs for each alternative. Figures ES-7 and ES-8 summarize the comparison of the alternatives according to both CERCLA and MTCA criteria. In summary, Alternatives 2 through 6 are predicted to achieve the RAOs, although over different time frames with different technologies and degrees of uncertainty. The major differences among the alternatives are the amount of active versus passive remedial actions implemented, as described above. The major differences among alternatives with the same RALs are the reliance on dredging for the active remediation portion of the "R" alternatives versus a combination of technologies (dredging, capping, and ENR) for the active remediation portion of the "C" alternatives.

The following summarizes the key points of the comparative analysis.

How the Alternatives Protect People Who Eat Resident Seafood from the LDW

For RAO 1 (human consumption of seafood), the sediment PRGs for PCBs and dioxins/furans are set at natural background, which is not predicted to be achieved in sediments under any alternative. The goal of Alternatives 2 through 6 is to reduce chemical concentrations as low as practicable given the ongoing inputs from the Green/Duwamish River. They would each make progress toward achieving RAO 1 through a combination of:

- Active cleanup (dredging and capping) to reduce chemical concentrations in sediment
- Natural recovery of the LDW as a whole to further reduce chemical concentrations in sediment over time, with contingency actions if projected MNR goals are not achieved
- Monitoring of sediments and seafood, to assess the anticipated reduction in chemical concentrations
- Further reducing exposures through seafood consumption advisories, public outreach, and education
- Periodic reviews to assess the effectiveness of the remedy and identify the need for changed approaches

Table ES-3: CERCLA and MTCA Evaluation Criteria for Detailed Analysis of LDW Remedial Alternatives

CERCLA		MTCA	
Type	**Criteria**	**Type**	**Criteria**
Threshold	Overall protection of human health and the environment	*Threshold*	Protect human health and the environment
			Comply with cleanup standards
	Compliance with ARARs		Comply with applicable state and federal laws
			Provide for Compliance Monitoring
Balancing	Long-term effectiveness and permanence	*Other Requirements*	Use permanent solutions to the maximum extent practicable[a]
	Reduction in toxicity, mobility, or volume through treatment		
	Short-term effectiveness		Provide for a reasonable restoration time frame[b]
	Implementability		
	Cost		
Modifying	State acceptance		Consider public concerns
	Community acceptance		

Notes:

a The MTCA requirement to "use permanent solutions to the maximum extent practicable" is evaluated using a disproportionate cost analysis that compares the alternatives against the following criteria:

1. Protectiveness
2. Permanence
3. Cost
4. Effectiveness over the long term
5. Management of short-term risks
6. Technical and administrative implementability
7. Consideration of public concerns

b The MTCA requirement to determine whether a cleanup action provides for a reasonable restoration time frame considers the following factors:

1. Potential risks posed by the site to human health and the environment
2. Practicability of achieving a shorter restoration time frame
3. Current use of the site, surrounding areas, and associated resources that are, or may be, affected by releases from the site.
4. Availability of alternative water supplies
5. Likely effectiveness and reliability of institutional controls
6. Ability to control and monitor migration of hazardous substances from the site
7. Toxicity of hazardous substances at the site
8. Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the site or under similar site conditions

Figure ES-6: Predicted Time to Achieve RAOs

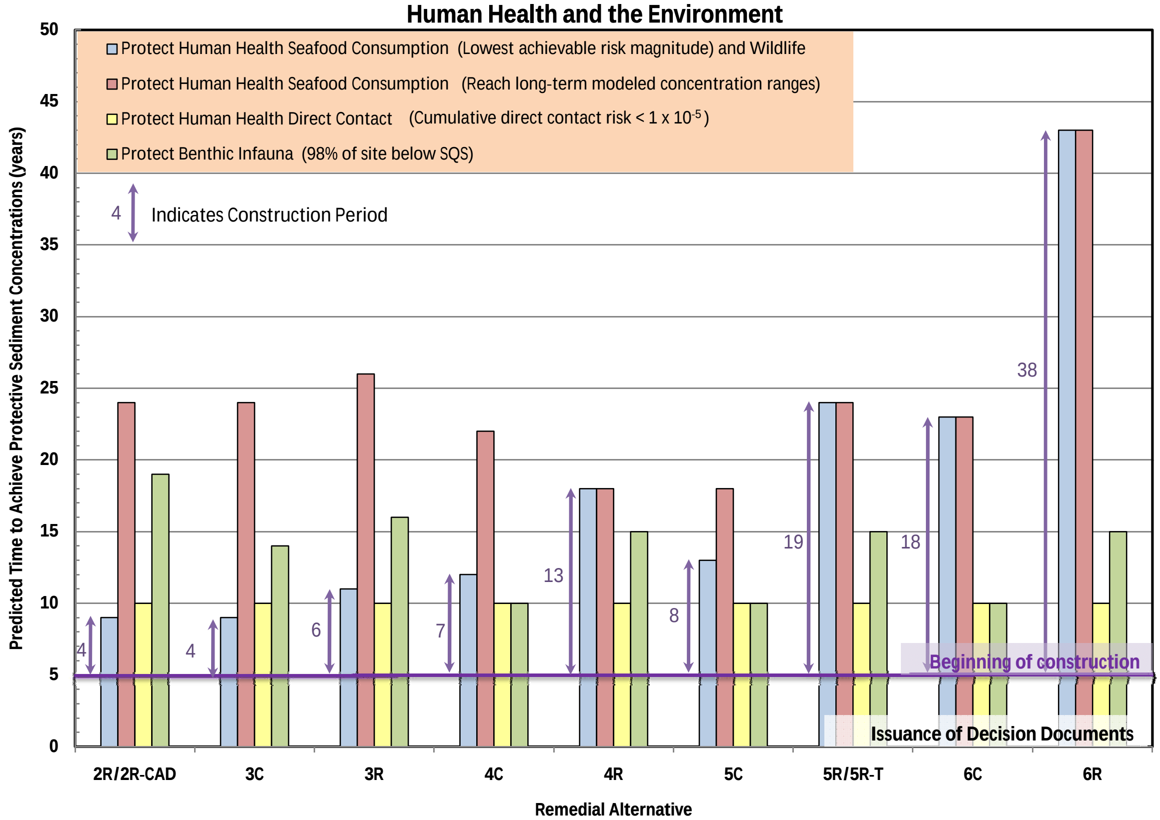


Figure ES-7: Comparative Analysis of Cleanup Alternatives

LDW Remedial Alternative	Cost (Net Present Value)	CERCLA Evaluation of Alternatives[a]: Meets Threshold Criteria[b]	Reduction in Toxicity, Mobility & Volume through Treatment [c]	Long-term Effectiveness	Short-term Effectiveness	Implementability	Cost [d]
1	$66 M	No	●	●	●	◒	⊙
2R-CAD	$210 M	Yes	●	◒	◒	◒	◓
2R	$230 M	Yes	●	◒	◒	○	◓
3C	$220 M	Yes	●	○	◓	○	◓
3R	$290 M	Yes	●	○	◓	○	○
4C	$290 M	Yes	●	◓	◓	◓	○
4R	$440 M	Yes	●	◓	○	◓	◒
5C	$310 M	Yes	●	◓	◓	○	○
5R	$550 M	Yes	●	⊙	◒	◒	◒
5R-T	$600 M	Yes	◒	⊙	◒	●	◒
6C	650 M	Yes	●	◓	◒	◒	◒
6R	$1,300 M	Yes	●	⊙	●	●	●

Notes:

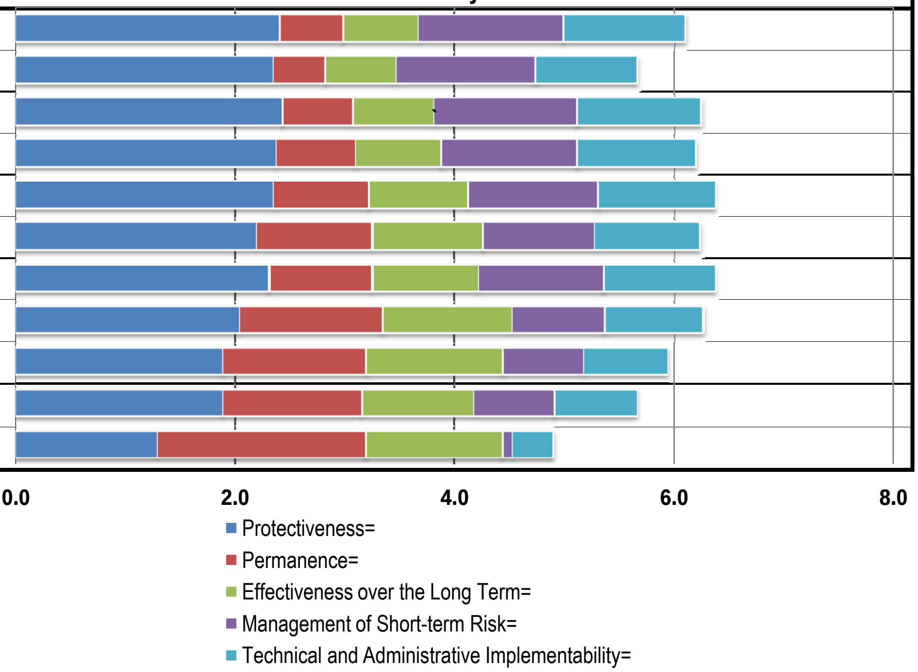
1. State, tribal, and community acceptance will be evaluated following formal public comment on the FS and EPA's proposed plan.

a Ratings based on rankings shown in Table 10-1.
b Threshold criteria are: 1) Overall Protection of Human Health and the Environment and 2) Compliance with ARARs.
c Treatment (soil washing) is a component of only Alternative 5R-T.
d Low costs are given a high rank and high costs are given a low rank.

⊙ - Ranks very high compared to other alternatives
◓ - Ranks relatively high compared to other alternatives
○ - Ranks moderate compared to other alternatives
◒ - Ranks low-moderate compared to other alternatives
● - Ranks low compared to other alternatives

Figure ES-8: MTCA Weighted Benefits for Individual Evaluation Criteria

Remedial Alternative	Actively Remediated Area (acres)[b]	Weighted Ratings Under MTCA[a] — Total Benefits by Criteria
2R	59	
2R-CAD	59	
3C	86	
3R	86	
4C	143	
4R	143	
5C	186	
5R	186	
5R-T	186	
6C	328	
6R	328	



Notes:

1. See Section 11 for details.=

a Ratings based on rankings= shown in Table 10-1.=

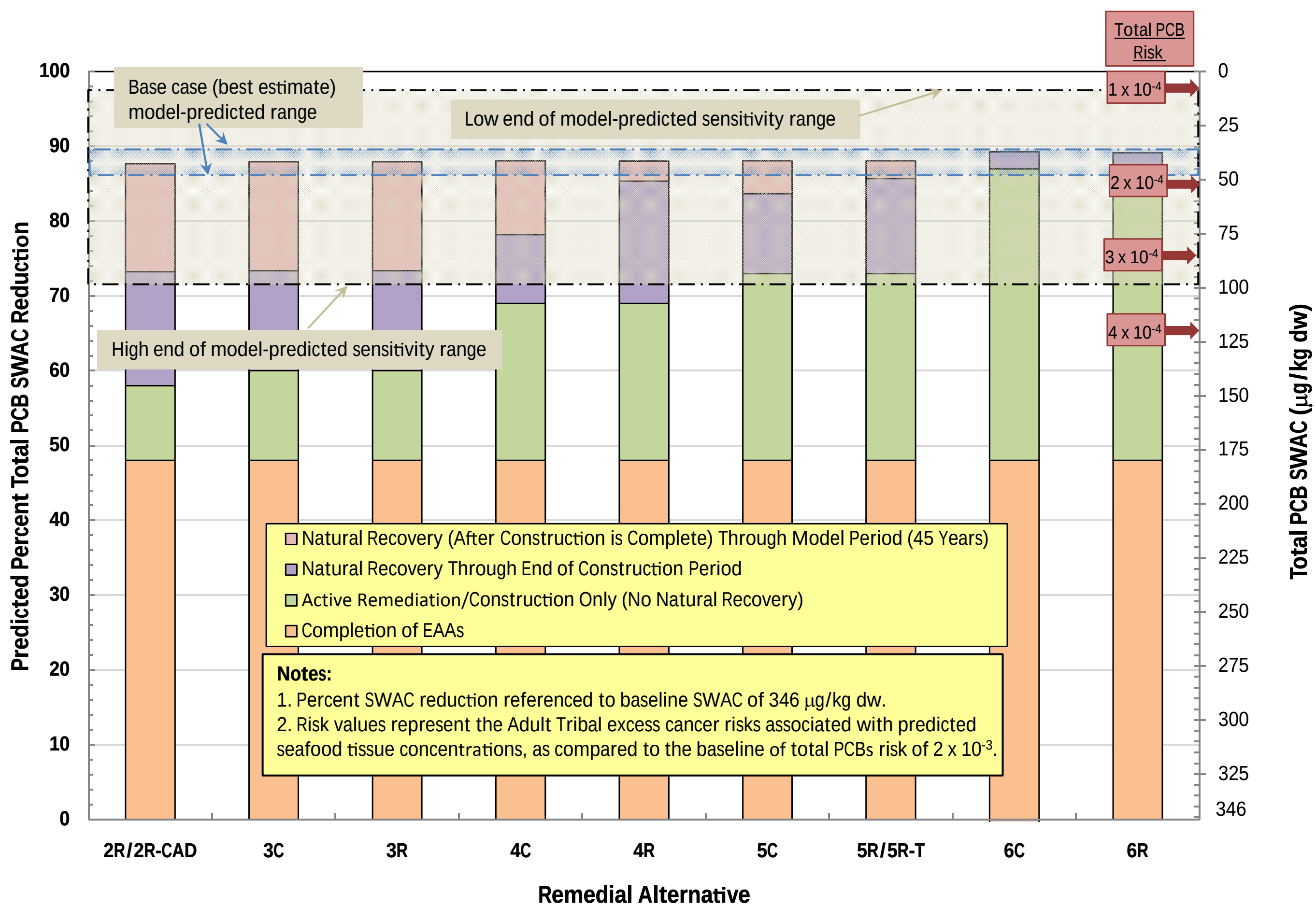
b Includes 29 EAA acres.=

C = combined technologies alternative; CAD = contained aquatic disposal; DCA = disproportionate cost analysis; MTCA = Model Toxics Control Act; R = removal emphasis; T= Treatment.=

Overall Protection of Human Health and the Environment

- Alternatives 2 through 6 are predicted to achieve similar levels of residual excess cancer risks, in the range of 1 in 10,000 (10^{-4} magnitude risk) or less, depending on the exposure pathway. These risks are within the acceptable risk range for CERCLA, but none of the alternatives reach the MTCA risk threshold of 1×10^{-6} for individual chemicals for the seafood consumption pathway.
- Alternatives 2 through 6 are predicted to reduce risks to humans that consume resident LDW seafood to a lifetime excess cancer risk in the range of 10^{-4} based on Adult Tribal and Asian and Pacific Islander RME scenarios (RAO 1). Lifetime excess cancer risks for the Child Tribal RME scenario are reduced to the range of 10^{-5}. Alternatives 2 through 5 rely to a certain extent on natural recovery to achieve this result (Figure ES-9).
- It is not technically feasible for any of the alternatives to achieve the total PCB and dioxin/furan PRGs for the human seafood consumption pathway because they are set at natural background concentrations. The sidebar on page ES-26 explains how these alternatives would achieve RAO 1.
- Alternatives 2 through 6 are predicted to reduce surface sediment chemical concentrations to levels that protect humans from adverse effects associated with direct contact with sediment (RAO 2). In all cases, active remediation alone reduces cumulative excess cancer risks from all four risk drivers and all exposure scenarios to no higher than 1 in 100,000 (1×10^{-5}). However, the individual risk posed by arsenic is greater than 1 in 1,000,000 (1×10^{-6}) because the natural background concentration of arsenic yields greater risks.
- Alternatives 2 through 6 are predicted to protect wildlife (RAO 4) by reducing total PCB concentrations

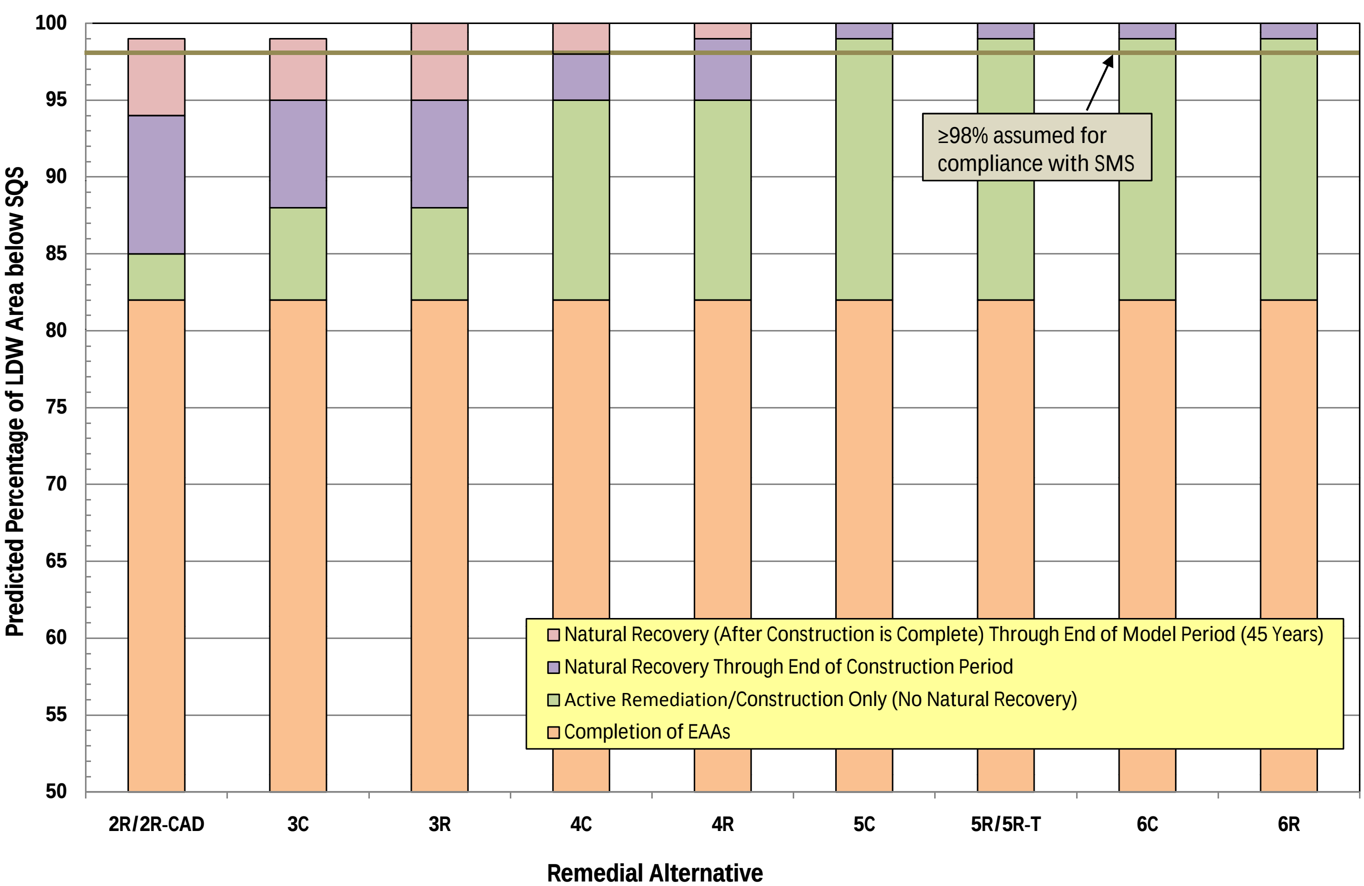
Figure ES-9: Contributions to Reduction in Total PCB Spatially Weighted Average Concentration by Active Remediation and Natural Recovery



below levels that correspond to a non-cancer HQ < 1 for wildlife that consume resident seafood. For Alternatives 4, 5, and 6, active remediation alone is sufficient to achieve the predicted concentration reductions; no contributions from natural recovery are required. Alternatives 2 and 3 require small incremental reductions in LDW-wide average total PCB concentrations by natural recovery to protect wildlife (Figure ES-10).

- Alternatives 2 through 6 are predicted to comply with MTCA/SMS requirements for protection of the benthic community. Alternatives 2R, 2R-CAD, 3C, 3R, 4C, and 4R rely to a certain extent on natural recovery to achieve this result (Figure ES-10).
- Differences in overall protectiveness of Alternatives 2 through 6 are largely in the context of short-term and long-term effectiveness. The alternatives with smaller active remedial footprints rely more on natural recovery to achieve the RAOs, while alternatives with larger active remedial footprints rely more on engineering controls such as dredging, capping, and ENR. Alternatives 2R, 2R-CAD, 3C, 3R, 4C, and 5C can be implemented more quickly and result in lower impacts to workers, the community, and the environment during implementation. However, use of engineering controls (dredging and capping) rather than MNR provides more certainty in estimated time frames and chemical concentrations left after cleanup. Alternatives with smaller active footprints (Alternatives 2 and 3) leave more subsurface contamination in place that could potentially be re-exposed.
- Alternatives that rely more on dredging have higher impacts in the short term and maintain high seafood tissue chemical concentrations over the implementation time frames. Implementation time frames are longer for dredging than for implementation of other active technologies over a similar area. However, they also leave less subsurface contamination in place and therefore have a reduced potential for material to become re-exposed in the future.

Figure ES-10: Contributions to Achievement of RAO 3 by Active Remediation and Natural Recovery



Lower Duwamish Waterway Group
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Compliance with ARARs

Because this FS is being conducted under a joint CERCLA and MTCA order, provisions of MTCA and the SMS are considered to be ARARs under CERCLA and governing requirements under MTCA/SMS. Alternatives 2R and 2R-CAD will take the longest to comply with the SMS. Natural background PRGs for PCBs and dioxins/furans (for RAO 1) in sediment are ARARs under MTCA because human health risk-based thresholds for seafood consumption are lower than natural background concentrations. None of the alternatives are expected to comply with these ARARs without reliance on institutional controls designed to reduce human exposure to resident fish and shellfish.

Significant water quality improvements are anticipated from sediment remediation and source control. Water quality is likely to be variable throughout the LDW, depending on the extent of local sources. Generally, the more quickly and thoroughly sources are controlled, the more quickly water quality improvements should occur. It is not anticipated that any alternative will comply with some of the federal or state ambient water quality criteria or standards, particularly those based on human consumption of bioaccumulative chemicals that magnify through the food chain (e.g., PCBs), because upstream concentrations exceed those criteria or standards.

CERCLA requires that all ARARs be met or waived on any one or more of six bases upon completion of remedial actions. By far the most common waiver is for technical impracticability. The goal in all instances where predictions are that ARARs may not be achieved is to get as close as technically practicable to the ARAR, and apply a waiver only to the extent necessary. Because future conditions are difficult to project, actual data available upon completion of the remedial actions will underlie the basis for any such waivers, which are formally documented and issued by EPA. For this reason, more definitive statements on whether, and perhaps more significantly to what extent, ARARs such as sediment PRGs for PCBs and dioxins/furans, or certain water quality criteria based on bioaccumulation of chemicals through the food chain, will be met or potentially waived cannot be made at this time, but must be made at the completion of cleanup and source control work at the site.

Long-term Effectiveness and Permanence

Residual risks from surface sediment are similar among Alternatives 2 through 6 based on model-predicted outcomes. Active remediation alone (i.e., ignoring any contribution from natural recovery) is responsible for the majority of progress toward achievement of residual risk levels for all alternatives. However, Alternatives 2, 3, and 4 rely more on natural recovery and thus have more uncertainty in predicted outcomes. Uncertainty in the residual risks from surface sediment is largely associated with the quality of incoming sediment from the Green/Duwamish River. Ultimately, surface sediment chemical concentrations are expected to converge to levels similar to the quality of incoming sediment from the Green/Duwamish River, resulting in similar levels of risk over time for Alternatives 2 though 6. While there is uncertainty in what future conditions may present (e.g., depending on the effectiveness of LDW source control efforts) it is likely that in the long term, average conditions will be similar, regardless of the alternative.

The remedial alternatives also differ in the amount of contaminated subsurface sediment remaining with concentrations above protective levels, which, if re-exposed or brought to the surface, could pose human health and/or ecological risks. These differences stem from alternative-specific variations in the relative areas managed by dredging, capping, ENR, or natural recovery. Alternatives that dredge across a greater surface area leave less contaminated subsurface sediment behind, which, in turn, reduces the risk of potential future exposures (e.g., by high-flow events or vessel scour). More capped surface area translates into lower risk from subsurface sediments than for areas addressed by ENR or MNR because caps are engineered to withstand scour or other disturbance under location-specific conditions.

Section 10 of this FS qualitatively discusses the potential to re-expose contaminated subsurface sediment remaining in areas that are neither dredged nor capped. Alternatives 5R and 6R are expected to have a "very low" potential for re-exposure of subsurface contamination because they leave the least amount of contaminated sediment behind. Alternatives 4C, 4R, and 5C leave an incrementally larger area managed by ENR and MNR and are expected to have a "low" potential for re-exposure. Alternatives 2 and 3 have even larger areas managed by ENR and MNR and are qualitatively ranked as having a "low to moderate" and "moderate" potential for this factor. A "high" potential for re-exposure is not warranted for Alternatives 2 through 6 because the remedial alternatives are designed to identify and actively manage areas more prone to natural or mechanical disturbances. In addition, monitoring, institutional controls, and contingency actions can be used to prevent or respond to problem areas.

Each of Alternatives 2 through 6 requires a set of controls consisting of monitoring, maintenance, and institutional controls, with contingency actions and periodic reviews (e.g., every 5 years). Differences among the alternatives are largely a matter of scope and duration (i.e., level of effort) for the controls and time to reach goals. Differences in the level of effort and reliability of these control mechanisms, once RAOs are achieved, are related primarily to the areal extent of remaining subsurface contamination.

Alternatives 2 through 6 rely on continued use of seafood consumption advisories and may include other public outreach designed to increase seafood consumers' awareness of risks and to reduce unacceptable exposures. The relative importance of this institutional control in overall risk communication and reduction is similar across all alternatives.

Outreach and notification to waterway users, review of U.S. Army Corps of Engineers (USACE) construction permit applications, and, where appropriate, the use of restrictive covenants or similar controls to avoid disturbance of subsurface contamination, will be required to varying degrees. The relative importance of this set of institutional controls is greater for the combined technology alternatives that emphasize capping, ENR, and natural recovery. Similarly, among the removal alternatives, this set of institutional controls is least important for Alternative 6R (the most removal) and has greater importance for Alternatives 2R and 2R-CAD.

Alternatives 2 through 6 progressively rank from low to high for long-term effectiveness and permanence, and the combined technology alternatives rank lower than the removal emphasis alternatives. This ranking is based primarily on the increased long-term effectiveness and permanence associated with removing contaminated sediments from the LDW, on decreasing institutional controls, and on the lower uncertainty associated with lesser amounts of contaminated sediment remaining in the subsurface following implementation.

Reductions in Mobility, Toxicity, or Volume through Treatment

Alternative 5R-Treatment is the only alternative that includes a treatment technology (soil washing).[4] Soil washing could decrease the volume of dredged sediment requiring upland disposal but not the mass of chemicals. Soil washing creates three fractions: 1) separated fine-grained material containing the majority of the contaminants; 2) the separated "clean" sand and gravel material containing low residual chemical concentrations; and 3) a large amount of wastewater containing low chemical concentrations. The treated sand fraction would require testing to quantify residual chemical concentrations and assess its suitability for potential beneficial reuse. Process wastewater requires treatment to reduce concentrations of residual contaminants prior to discharge. Depending on how the material fractions are handled, residual contaminants can pose a different exposure potential to human health and the environment.

Removal and disposal, capping, ENR, and MNR are not categorized as treatment technologies under CERCLA. Thus, each alternative except Alternative 5R-Treatment is ranked equally. Alternative 5R-Treatment ranks slightly higher because the volume of contaminated sediment requiring disposal may be reduced.

Short-term Effectiveness

Alternatives are evaluated for their ability to protect the community, workers, and the environment during implementation. Also, the evaluation of short-term effectiveness considers the time required to achieve RAOs.

Alternatives with longer construction times and greater dredge volumes present proportionately larger risks to workers, the community, and the environment, and therefore generally rank lower for these short-term effectiveness factors. Longer construction periods increase equipment and vehicle emissions, noise, and other resource uses. Larger actively remediated footprints increase short-term disturbance of the benthic community and other resident aquatic life and release more bio-available chemicals over longer construction time frames.

4 Carbon amended or other reactive caps were not specifically evaluated as part of remedial alternatives that construct engineered caps, but amended caps may be considered during remedial design. Amended caps have toxicity and mobility reduction characteristics and have been successfully used in a number of regional capping projects, including the Olympic View Resource Area and Thea Foss Waterway in Tacoma, and Upriver Dam in Spokane, and they are included in the design for the Slip 4 EAA.

Alternatives 2 through 6 are predicted to achieve RAOs at or within 10 years of construction completion, except Alternatives 2 and 3 require an additional 5 years to achieve long-term model predicted concentrations. The alternatives differ significantly in their construction time period. Alternatives that emphasize removal have longer construction times than the combined alternatives. As an example, Alternative 6R has a construction time of 38 years versus 18 years for Alternative 6C. Figure ES-6 illustrates the time required to achieve the RAOs for the remedial alternatives.

Alternatives 3C, 4C, and 5C are predicted to achieve all 4 RAOs in the shortest time frames (14, 12, and 13 years respectively), excluding the time to reach long-term model predicted concentrations. Alternatives 2R, 2R-CAD, 3R, and 4R have moderately long time frames (19, 19, 16, and 18 years respectively) to achieve the RAOs. Note, however, that the limiting factors are different. Alternatives 2R, 2R-CAD, and 3R require time beyond the construction period to achieve RAO 3 through natural recovery, whereas the limitation for Alternative 4R is the construction period. Natural recovery and construction timing estimates both have uncertainty. Alternatives 5R, 6C, and 6R have the longest predicted time frames to achieve the RAOs (24, 23, and 43 years respectively), by virtue of their long construction periods. Alternatives 3C, 3R, 4C, and 5C are ranked relatively high for short-term effectiveness, because of their short construction periods, low environmental impacts, and short time frames to achieve RAOs. Alternatives 5R, 5R-Treatment, 6C, and 6R are ranked low because they have the largest impacts on workers, the community, and the environment during construction and relatively long construction time frames. Alternatives 2R and 2R-CAD are also ranked low because they have the greatest uncertainty with respect to the predicted time frames to achieve RAOs.

Implementability

Technical feasibility, administrative feasibility, and availability of services and materials are factors considered under this criterion. The implementability evaluation focuses primarily on the first two factors because, with one exception (5R-Treatment), the alternatives use the same types of technologies or use the same types of equipment and methods, all of which are available and for which expertise exists in the Puget Sound region.

Alternatives with shorter construction periods are easier to implement through the end of the construction period than those with longer construction periods. This reduces the overall level of difficulty both technically and administratively (e.g., coordination with agencies) and the potential for technical problems leading to schedule delays. Alternative 2R is highly implementable. Alternative 2R-CAD has administrative feasibility issues associated with siting, using, and maintaining one or more CAD facilities. Alternatives 3C, 4C, and 5C have relatively short construction periods and are flexible in terms of the technology mix, which is important in terms of reducing technical problems that could lead to schedule delays. In this same context, Alternatives 3R and 4R are less flexible and therefore have greater potential for technical difficulties and delays. Alternatives 5R, 5R-Treatment, 6C, and 6R are the most complex to implement in that they have the longest construction periods. Also, these alternatives have low RALs. Low RALs can complicate compliance verification during dredge operations despite best efforts at managing resuspension and dredge residuals. Also, Alternative 5R-Treatment has technical and administrative challenges associated with siting and operating a treatment facility, and finding an acceptable use for treated sediment.

After construction, additional implementability considerations come into play and must be balanced against those discussed above. Alternatives that rely more on MNR to achieve PRGs have an increased potential for requiring actions in the future (e.g., more dredging). This results in an increased technical and administrative burden of evaluating monitoring data over time, considering the need for contingency actions if cleanup levels are not achieved in the predicted time frame, and implementing contingency actions. In this context, alternatives that rely to a greater extent on active construction to achieve PRGs are more favorable.

In combination, these considerations result in lower implementability rankings for Alternatives 2R, 2R-CAD, 5R, 6C, and 6R. Alternatives 3C, 3R, and 5C receive moderate implementability rankings. 3C and 3R are in the low to mid-range for complexity and 5C does not rely to a great extent on natural recovery to achieve PRGs, and therefore has a lower potential for requiring contingency actions. Alternatives 4C and 4R receive the highest rankings because they represent the best balance of the implementability factors.

Cost

Alternative 6R has the highest cost ($1,300 million) and therefore ranks lowest for this criterion. Alternatives 4R, 5R, and 6C are ranked next; costs for these alternatives range from $450 to $630 million. Alternatives 3R, 4C, and 5C ranked higher, with costs just under $310 million each. Alternatives 2R, 2R-CAD, and 3C have the lowest costs and are ranked most highly.[5]


Courtesy of Port of Seattle

5 The estimated EAA (Alternative 1) cost of $66 million and costs associated with upland cleanup and source control (not estimated) are not included in the cost estimates for Alternatives 2 through 6.

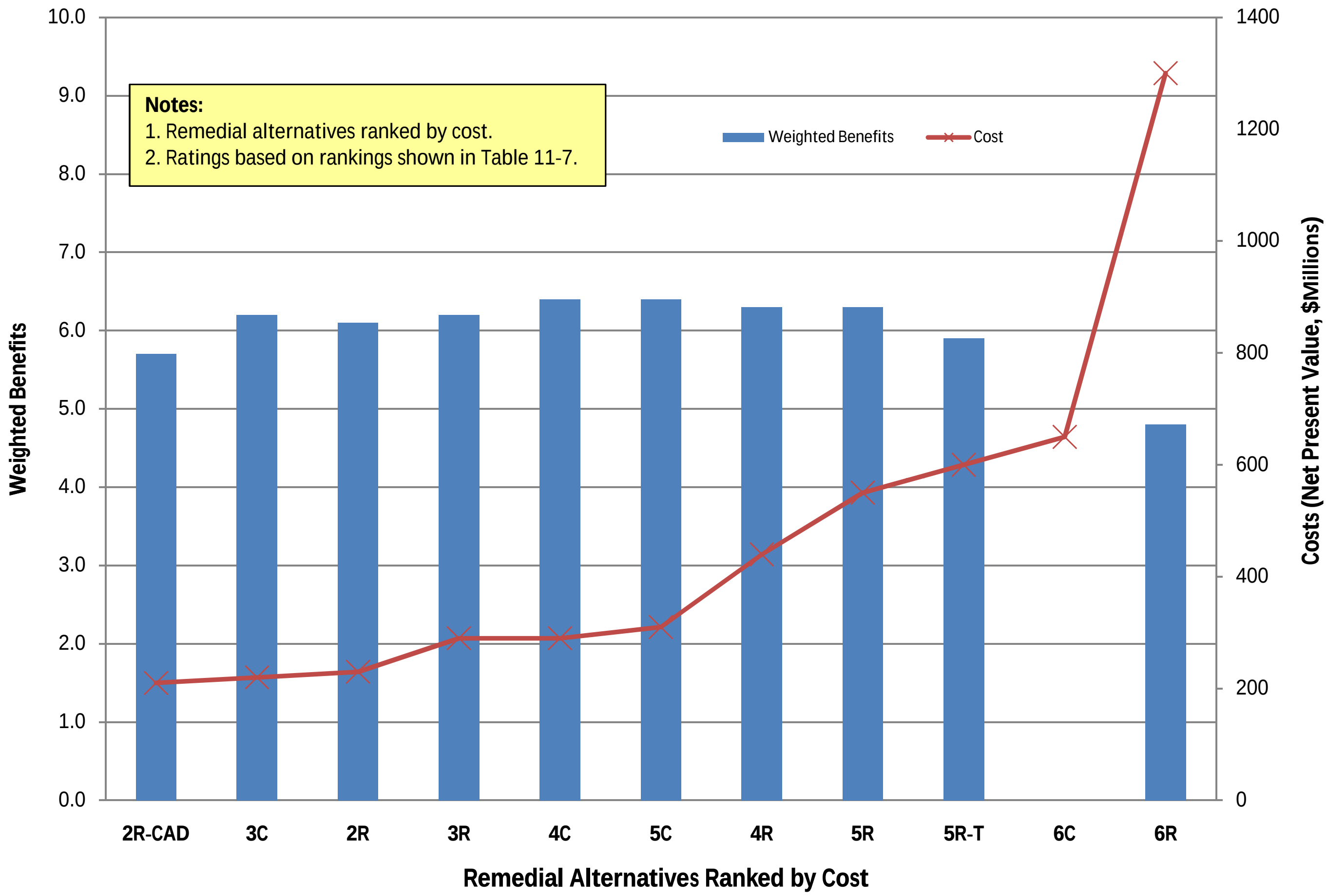
Summary of MTCA Disproportionate Cost Analysis

MTCA provides a method of summarizing the net benefits of alternatives across the multiple criteria discussed above. Figures ES-8 on page 29 and ES-11 summarize the total benefits and costs of the alternatives using the MTCA criteria.

The MTCA disproportionate cost analysis (DCA) uses six remedy evaluation criteria, which are similar to, but not exactly the same as the CERCLA comparative analysis criteria. Under MTCA, the evaluation criteria are protectiveness, permanence, effectiveness over the long term, management of short-term risks, technical and administrative implementability, and consideration of public concerns. Like the CERCLA comparative analysis, the DCA compares remedial alternatives using summary data for each alternative, such as the predicted risks resulting from contamination following remediation (e.g., carcinogenic risk from seafood consumption), the amount of time to achieve RAOs, the volume of contaminated sediment removed, construction time frame, and others. However, there are specific differences in the factors that are considered under each evaluation criterion, which can result in different results among alternatives between the two analyses. Unlike the CERCLA comparative analysis, these metrics have been converted into numerical scores, which are combined for a total benefit score. Finally, these scores are compared with the cost of each alternative as a means of comparing the benefit of each alternative relative to its cost. Alternative 1, No Further Action, is included in the CERCLA comparative analysis, but is not included in the DCA because it does not satisfy MTCA threshold requirements.

Figure ES-8 (page 29) shows the results of the MTCA DCA for total benefits. MTCA requirements do not prescribe standard metrics and methods for conducting a DCA; therefore, best professional judgment and precedent from other sites were used to construct the DCA for the LDW. Final determinations about disproportionate costs will be made by Ecology in consultation with EPA. The results show that Alternatives 2 through 6, excluding 6R, score in the same range (5.7 to 6.4 total benefit points), and Alternative 6R scores lower (4.9). The majority of the remedial alternatives score roughly equivalently for these reasons: 1) the predicted risks resulting from recontamination after remediation are roughly the same for all alternatives—this is specific to the conditions of the LDW; and 2) the evaluation criteria tend to balance each other. For example, mass removal of sediment tends to score higher for permanence, but lower for management of short-term risks. Alternative 6R scores significantly lower than the other alternatives because a very low RAL and removal-emphasis results in short-term risks and implementability challenges that outweigh other benefits. In comparing benefit scores to costs, Figure ES-11 shows that additional costs do not necessarily add proportional benefit for the remediation of contaminated sediment in the LDW. Specifically, the chart indicates that Alternatives 2R, 2R-CAD, 3R, 3C, 4C, and 5C have a relatively similar benefit-to-cost relationship, while the remaining alternatives show a pattern of diminishing benefits with increasing costs.

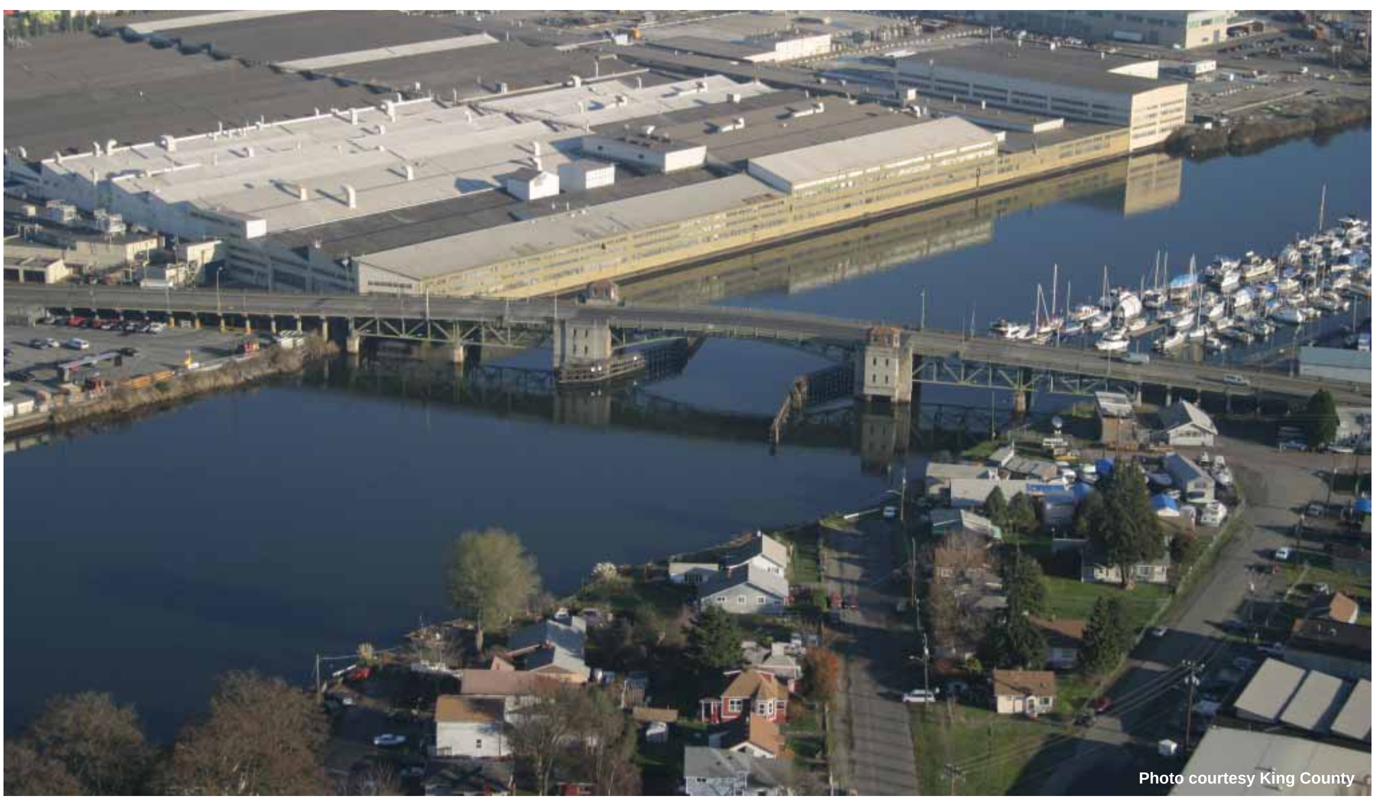
Figure ES-11: Benefits and Costs for Remedial Alternatives



Expected Outcomes and Uncertainties

The remedial alternatives are estimated to require one to four decades to implement and achieve cleanup objectives. Therefore, the cleanup actions, particularly those that rely more on MNR, may need to be adapted to new information as it becomes available. Remedial alternatives that rely more on MNR address this uncertainty by including the expectation that monitoring, adaptive management, and contingency actions will be a larger part of these alternatives. The FS analyses lead to the following predictions (uncertainties in these predictions will need to be considered in the decision-making process):

- The remedial alternatives are expected to significantly reduce seafood consumption risks (to humans and wildlife) after they are implemented. However, seafood consumption risks can be expected to remain elevated, particularly during the construction of all alternatives, as a result of the disturbance of contaminated sediments. The estimated construction periods range from 4 years for Alternative 2 to 38 years for Alternative 6R. Actual changes in seafood consumption risks will require monitoring over time.
- For each alternative, LDW surface sediments are predicted to equilibrate to similar chemical concentrations, reflecting the composition of upstream sediments and other inputs. While source control efforts will have some effect on reducing long-term sediment concentrations, chemical concentrations entering the LDW on sediments from upstream are predicted to have the greatest effect on long-term sediment chemical concentrations because they constitute about 99% of the mass of sediments depositing in the LDW. According to the modeling, time to reach equilibrium conditions ranges from 20 to 30 years. However, model projections 20 to 30 years in the future have high uncertainty both in the long-term sediment chemical concentrations and the time to achieve them. For this reason, evaluation of changes over time predicted by modeling requires confirmation over time through monitoring.
- For Alternatives 2 through 6, excess cancer risks based on Adult Tribal and Asian and Pacific Islander RME seafood consumption rates are predicted to remain in the 10^{-4} range, even after equilibrium conditions are



On the Lower Duwamish Waterway, industrial and commercial facilities line the shoreline, and two long-established residential communities (Georgetown and South Park) are neighbors.

reached. Alternatives 2 through 6 would achieve RAO 1 through a combination of:

– Active cleanup to reduce chemical concentrations in surface sediment
– Natural recovery of the LDW as a whole to further reduce chemical concentrations in surface sediment over time to as low as practicable given the on-going inputs to the LDW
– Monitoring of sediments and seafood, to assess anticipated reduction in chemical concentrations
– Continued source control efforts in a complementary program led by Ecology
– Institutional controls designed to reduce human exposures and manage remaining risks associated with resident seafood consumption
– Periodic reviews to assess the effectiveness of the remedy and identify the need for contingency actions

- Alternatives 2 through 6 are predicted to achieve RAOs 2, 3, and 4 with high but varying degrees of certainty. In most cases, these RAOs are achieved at the end of construction or within 10 years following construction completion. An additional period of natural recovery is needed to achieve RAO 3 for Alternatives 2 through 4 and to achieve long-term, model-predicted sediment chemical concentrations for all the alternatives other than Alternative 6.

- Long-term monitoring (for both operations and maintenance and RAO compliance) and source control measures will be necessary for each alternative.

- Alternatives that rely on greater amounts of engineering controls, particularly dredging and capping, have greater certainty in predicted outcomes. Alternatives that remove more contaminated sediments from the LDW have more long-term certainty than alternatives where more subsurface contaminated sediments remain in place and will require long-term management. Predicted outcomes are less certain for alternatives that employ greater use of MNR because of the uncertainties associated with model predictions. Contingency actions based on monitoring results are included in these alternatives to manage uncertainties during implementation and future monitoring. Interim goals can be set based on predicted expectations and the alternatives can be adapted as new information is developed, during remedial design, construction, and the execution of the site-wide monitoring program.

- Because of the complexity of urban systems and sediment cleanups, it is recognized that there is uncertainty in both the short- and long-term effectiveness of all remedial technologies presented in this FS. All technologies have short-term uncertainties associated with implementation and maintenance (e.g., dredge residuals, extent of cleanup, coordination and timing of actions). Technologies associated with removal have uncertainties associated with the extent and completeness of removal. Technologies that leave contaminated sediment behind (e.g., capping, ENR, MNR) are subject to long-term uncertainties about technology performance and sediment stability (e.g., hydrologic/hydraulic conditions, sediment deposition rates, bioturbation, scour, recolonization). Uncertainties associated with technology performance can be managed through adaptive management practices that include comprehensive monitoring programs and defined contingency actions to address performance issues (e.g., recontamination of surface sediment, re-exposure of buried contaminated sediment). Many of these potential uncertainties have been incorporated into the cost estimates.

- The FS cost estimates are subject to considerable uncertainty at this stage in the remedial process, but are considered adequate for evaluation of the remedial alternatives. The cost estimates are particularly sensitive to dredge volume estimates, although several other factors were considered in evaluating cost uncertainties.

Photo courtesy City of Seattle

Conclusions

Many factors need to be considered during the selection of a remedial alternative for the LDW. That analysis will be conducted by EPA and Ecology and integrated into EPA's Record of Decision for the LDW based on input received from review of the Final FS and Proposed Plan. To aid the public in reviewing this FS, some of the key differences and similarities among the alternatives in the CERCLA and MTCA comparative analysis are highlighted in Table ES-4. They are summarized below along with some key conclusions. Again, Alternative 1 is not discussed.

CERCLA and MTCA Compliance: Alternatives 2 through 6 are predicted to achieve RAOs and meet CERCLA and MTCA threshold criteria, although long-term compliance with certain ARARs will need to be evaluated based on future monitoring.

Predicted Residual Risks for Seafood Consumption (RAO 1): Seafood consumption risks associated with PCBs are predicted to be similar among Alternatives 2 through 6, both immediately after construction and over time. Total excess cancer risks from seafood consumption from all chemicals cannot be reliably predicted, but are expected to be similar among alternatives based on similar residual sediment chemical concentrations. Elevated chemical concentrations in fish and shellfish tissue will persist under any of the alternatives and necessitate continuation of seafood consumption advisories in the LDW. However, it is possible that the seafood consumption advisories could be modified over time.

Other Risks (RAO 2, RAO 3 and RAO 4): Alternatives 2 though 6 achieve similar levels of risk reduction for direct contact, benthic protection, and protection of wildlife. These alternatives are considered protective of humans and the environment.

Predicted Surface Sediment Concentration Reduction: Over time, the alternatives are predicted, with varying degrees of certainty, to achieve similar reductions in PCB and other risk-driver concentrations in sediment. The greatest reduction in LDW-wide chemical concentrations (and hence risks) will result from managing the previously identified EAAs (Alternative 1) and other hot spots (Alternatives 2R and 2R-CAD).

Long-Term Model Predictions: The alternatives differ in how PCB reductions are achieved. Figures ES-9 and ES-10 show that the alternatives rely on active remediation and natural recovery to differing degrees. Figure ES-12 illustrates the expected time frames for reducing LDW-wide average total PCB concentrations during and after construction of the remedial alternatives. This figure also illustrates the long-term, model-predicted sediment chemical concentrations and the uncertainty around the model input parameters. While there is uncertainty in what future conditions may present (e.g., depending on the effectiveness of LDW source control efforts), it is likely that in the long-term, average conditions will be similar, regardless of the alternative.

Long-term Amount of Subsurface Contamination Remaining In Place: The alternatives differ significantly in the amount of contaminated sediment removed from the LDW. Alternatives with greater volumes of removal are generally considered to have greater permanence.

Monitoring Requirements: Alternatives 2 through 6 each require long-term monitoring to be protective. The alternatives differ in the total area that requires maintenance and certain types of monitoring, as illustrated in Table ES-4.

MNR and ENR Performance: Alternatives 2R, 2R-CAD, 3C, and 3R include over 100 acres of MNR. Alternatives 4C and 4R include 43 acres of MNR. The largest ENR areas are in Alternatives 5C and 6C (See Figure ES-5). The cost estimates for alternatives include contingency actions for both ENR and MNR areas as part of an adaptive management strategy.

Short-term Impacts during Construction: The alternatives have significantly different environmental impacts during construction, both in duration and overall magnitude. These include disturbances to habitat, elevated chemical concentrations in fish and shellfish tissue during and after active dredging, consumption of landfill space, and traffic and air emissions related to off-site transport of dredged material. The impacts are largely a function of the extent and duration of dredging and disposal activities. Therefore, alternatives with greater volumes of removal are considered to have greater short-term impacts.

Table ES-4: Summary of Similarities and Differences among Remedial Alternatives

Evaluation Criteria		Representative Measures of Difference	Site-wide Remedial Alternative											
			1	2R	2R CAD	3C	3R	4C	4R	5C	5R	5R-T	6C	6R
Overall Protection of Human Health and the Environment / Compliance with ARARs	Risk Reduction	Residual Risk from Total PCBs: Tulalip Reasonable Maximum Exposure Excess Cancer Risk[a, b] (based on time to reach modeled long-term concentration range in surface sediment)	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}
		Direct Contact: Cumulative Excess Cancer Risk[c]	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 0^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-5}$
		Benthic Protection: Percent of Stations with SQS Exceedances Managed[d]	95%	98%	98%	>98%	>98%	>98%	>98%	>98%	>98%	>98%	>98%	>98%
		Ecological Protection: HQ for Consumption of Seafood (Without Juvenile Fish) by River Otter (immediately following construction)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
		% PCB SWAC Reduction Attributable to Construction (from baseline)[e]	48	58	58	62	62	69	69	73	73	73	87	87
		% PCB SWAC Reduction Attributable to Natural Recovery when the modeled long-term concentrations are achieved (from baseline)	See note f	28	28	25	25	17	17	13	13	13	2	2
	Meets Threshold Requirements		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Long-Term Effectiveness and Permanence		Performance Dredge Volume (MM cy)[g]	Not estimated	0.62	0.62	0.57	0.79	0.74	1.2	0.77	1.5	1.5	1.7	3.6
		Total MNR Application Area (acres)	0	127	127	100	100	43	43	0	0	0	0	0
		Monitoring and Notification of Waterway Users (based on total cap, ENR, and MNR area; acres)	No institutional controls	130	153 (includes 23 acres of CAD)	128	105	106	54	103	12	12	113 in AOPC 1[h] and 80 outside of AOPC 1	16 in AOPC 1[h] and 12 outside of AOPC 1
Short-Term Effectiveness	Impacts Due to Construction	Ecological – Area Above -10 ft MLLW Disturbed (acres)	n/a	12	12	27	27	42	42	59	59	59	98	98
		Greenhouse Gas Emissions (CO_2; metric tons)	Not calculated	25,000	20,000	25,000	33,000	34,000	52,000	37,000	66,000	54,000	78,000	153,000
		Transportation – truck and train miles[i]	Not calculated	506,000	253,000	461,000	639,000	601,000	985,000	630,000	1,249,000	937,000	1,374,000	2,938,000
	Time Frames	Construction Time[j]	< 5	4	4	4	6	7	13	8	19	19	18	38
		Time to Meet RAOs[j]	n/a	19	19	14	16	12	18	13	24	24	23	43
		Time to reach modeled long-term concentration ranges site-wide (yrs)[j]	n/a	24	24	24	26	22	18	18	24	24	23	43
Costs		Total Costs (net present value, MM$)[l]	66	230	210	220	290	290	440	310	550	600	650	1,300

Notes:

a Risk estimate based on use of the total PCB SWAC [using base case (mid input values) BCM output] in the food web model. Total excess cancer risks (all carcinogens combined) are expected to be similar to total PCB risks for the consumption of resident fish and crab because most of the seafood consumption risk for these seafood types is from PCBs.

b See Table 9-6a for other RME risk scenarios. See Appendix M for site-related risk reduction calculations.

c No alternative achieves 1×10^{-6} excess cancer risk for arsenic for the direct contact tribal clamming and total beach play areas because background exceeds that risk level. cPAHs in Beach 3 may exceed 1×10^{-6} direct contact risk level due to recontamination.

d SQS station exceedances managed as a percent of total stations in FS dataset (n=1,395) 10 years following end of construction.

e PCB SWAC reduction attributable to construction of EAAs is included (48%).

f While natural recovery processes would occur, no monitoring or evaluation of these processes is included in Alternative 1.

g Estimated total dredge volume for EAAs is not available. The base-case performance dredge volume is the preliminary dredge volume plus additional volume for technology assignment and performance-based contingency assumptions (e.g., 15% of MNR areas are assumed to require dredging based on long-term RAO monitoring results).

h The total number of acres includes 19 acres of verification monitoring in AOPC 1 that are actively remediated in Alternative 6.

i Sediment is assumed to be disposed of by trucking from a transloading area to an intermodal station, where it is loaded onto train cars for transport to a landfill in Eastern Washington or Eastern Oregon. Trucking miles are estimated using an average 28 tons/truck and 12 miles (round trip) to the intermodal station. Train miles are estimated assuming 568 miles (round trip) to the landfill and 100 cars per train.

j Construction time is the estimated period for completing in water construction activities. Initiation of site cleanup begins after the issuance of decision documents for the LDW and includes initial remedial design activities, baseline monitoring, and completion of the EAAs (all of which is expected to require up to 5 years). After this time, construction of the selected alternative would begin. The estimated time to meet RAOs includes these first five years. The remedial alternatives cannot achieve the total PCB and dioxin/furan PRGs for the seafood consumption scenario. Therefore, two times are considered for achieving RAO 1: 1) the remedial alternative's implementation time, and 2) the predicted time for risk-driver concentrations to achieve long-term modeled concentration ranges. Estimated times are rounded to the nearest year. Additional time beyond implementation may be required for fish and shellfish tissue levels and ecologically sensitive areas to recover.

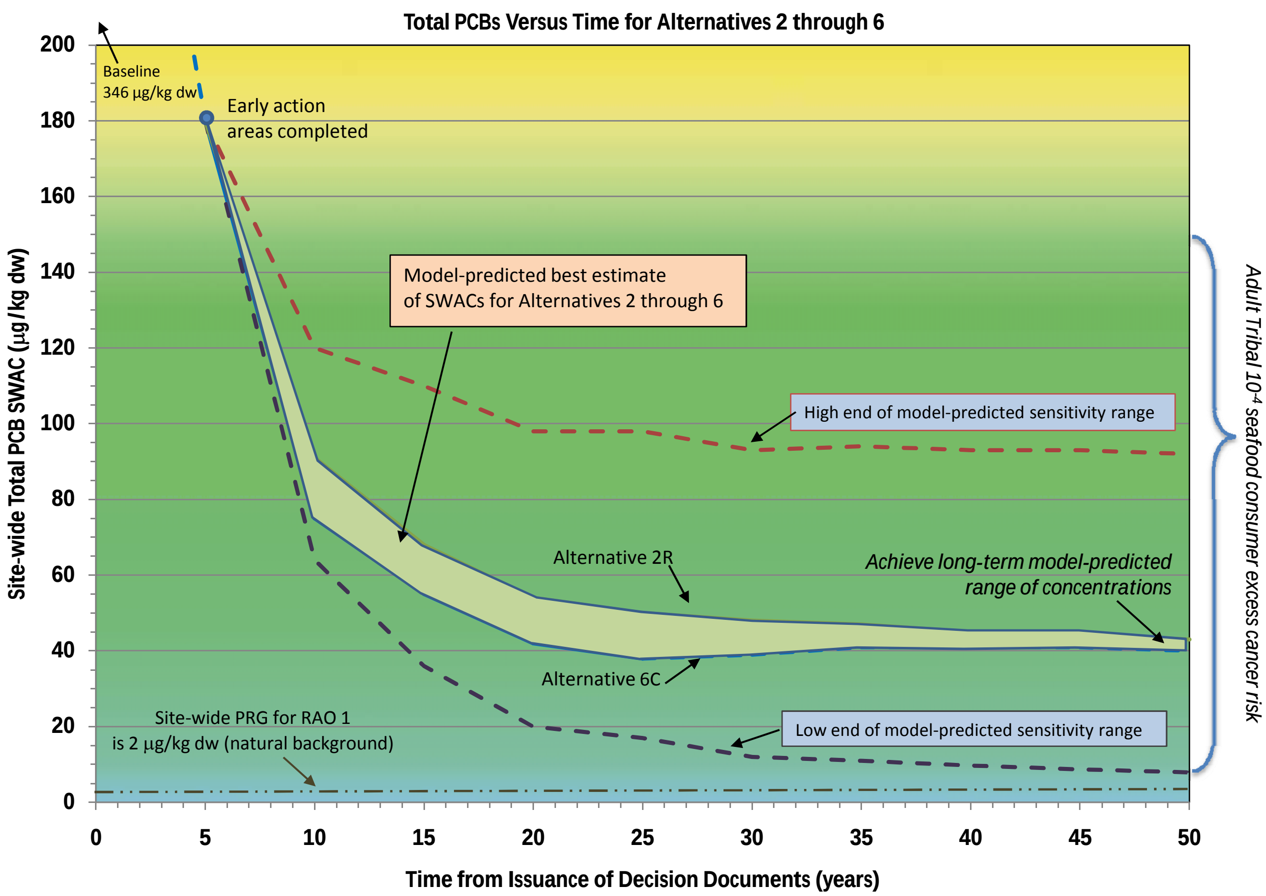
l See footnote (g) for removal volume assumptions used in cost estimates. Estimated cost of $66 million for Alternative 1 (EAAs) is not included in cost totals for the other alternatives.

Construction Time Frames: The alternatives have significantly different construction time frames. Alternatives 2R, 2R-CAD, 3C, 3R, 4C, and 5C have estimated construction time frames of 4 to 8 years, whereas 4R, 5R, 5R-Treatment, and 6C have construction time frames ranging from 13 to 19 years. Alternative 6R has the longest construction time frame (38 years). Site cleanup begins after the issuance of decision documents for the LDW; during the first five years, activities include initial remedial design activities, baseline monitoring, and completion of the EAAs. After this time, construction of the selected alternative would begin.

Predicted Time to Achieve RAOs: The predicted time to achieve long-term residual risk levels is influenced by how long it takes to construct an alternative, what is achieved by construction alone, the rate of natural recovery, and the success of source control measures. Greater reliance on natural recovery has a minor effect on the long-term surface chemical concentrations but increases the uncertainty of how long it will take. The alternatives differ in their predicted time to achieve the RAOs. Alternatives 3C, 4C, and 5C are predicted to achieve all 4 RAOs in the shortest time frames of 14, 12, and 13 years respectively. Alternatives 5R, 5R-Treatment, 6C, and 6R have the longest predicted time frames to achieve the RAOs (24, 23 and 43 years respectively), by virtue of their long construction periods. Further incremental reductions in risk-driver concentrations are expected to occur over time as a result of source control and natural recovery processes. These incremental reductions are more pronounced for the alternatives that rely more on natural recovery. There is uncertainty in time frames associated with both MNR predictions and construction time frames.

Costs: The alternatives vary significantly in costs, with a range of $210 million to $1.3 billion. There are also noticeable differences among the alternatives in the MTCA benefit-to-cost relationship. Alternatives 2R, 2R-CAD, 3C, 3R, 4C, and 5C have significantly lower costs per benefit achieved than the other alternatives. For a given RAL, the combined alternatives are less expensive than the removal alternatives.

Figure ES-12: Total PCB Predicted Spatially Weighted Average Concentration Versus Time for All Alternatives



Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company

Next Steps

This FS provides the basis for obtaining input from many interested parties. EPA, Ecology, and LDWG intend to solicit input from the public, including a broad range of stakeholders, and incorporate this input into the Final FS, which will be completed in 2011. The Agencies will then issue a proposed plan that identifies a preferred remedial alternative for the LDW. Formal public comment will be received on the proposed plan. After public comments on the proposed plan are received and evaluated, EPA will select the final remedial alternative, after seeking concurrence with Ecology pursuant to the April 2004 *Memorandum of Understanding between EPA and Ecology for the Lower Duwamish Waterway Site* (EPA and Ecology 2004).

This FS has assumed that a period of 5 years would be required following the Record of Decision and before the start of remedial construction. During this period, the following activities would occur:

- Completion of the EAA cleanups
- Completion of source control sufficient to begin remedial actions. It is anticipated that source control will be implemented in parallel with the sequencing of remedial actions
- Negotiation and entry of consent decrees or issuance of unilateral administrative orders for remedial design and implementation
- Sampling to refine priority areas requiring remediation and completion of initial remedial design
- Site-wide sampling to establish baseline conditions with which future post-remediation monitoring results will be compared
- Implementation of institutional controls addressing seafood consumption risks under RAO 1.

Photo courtesy Windward Environmental

Photo courtesy Port of Seattle

Photo courtesy Windward Environmental